# HOP Transit Study
# Existing Conditions and Choices Report

For the City of Boulder

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# 1 Executive Summary

*This Executive Summary contains the highlights of the following report. Some content is repeated here, from later in the report, and some is unique.*

## Introduction

The HOP is a two-way transit loop around the center of Boulder. It serves most of the city's densest residential and employment areas, and other major destinations, including the University of Colorado (CU), downtown, Pearl Street, Boulder Junction and the 29th Street Mall.

When ridership on the entire route is summed and averaged, the route is moderately productive compared to other frequent routes in Boulder. This average hides a more interesting picture: most of the route's ridership is happening on just a short segment, between the 29th Street Mall and CU. On the rest of the route, ridership is low.

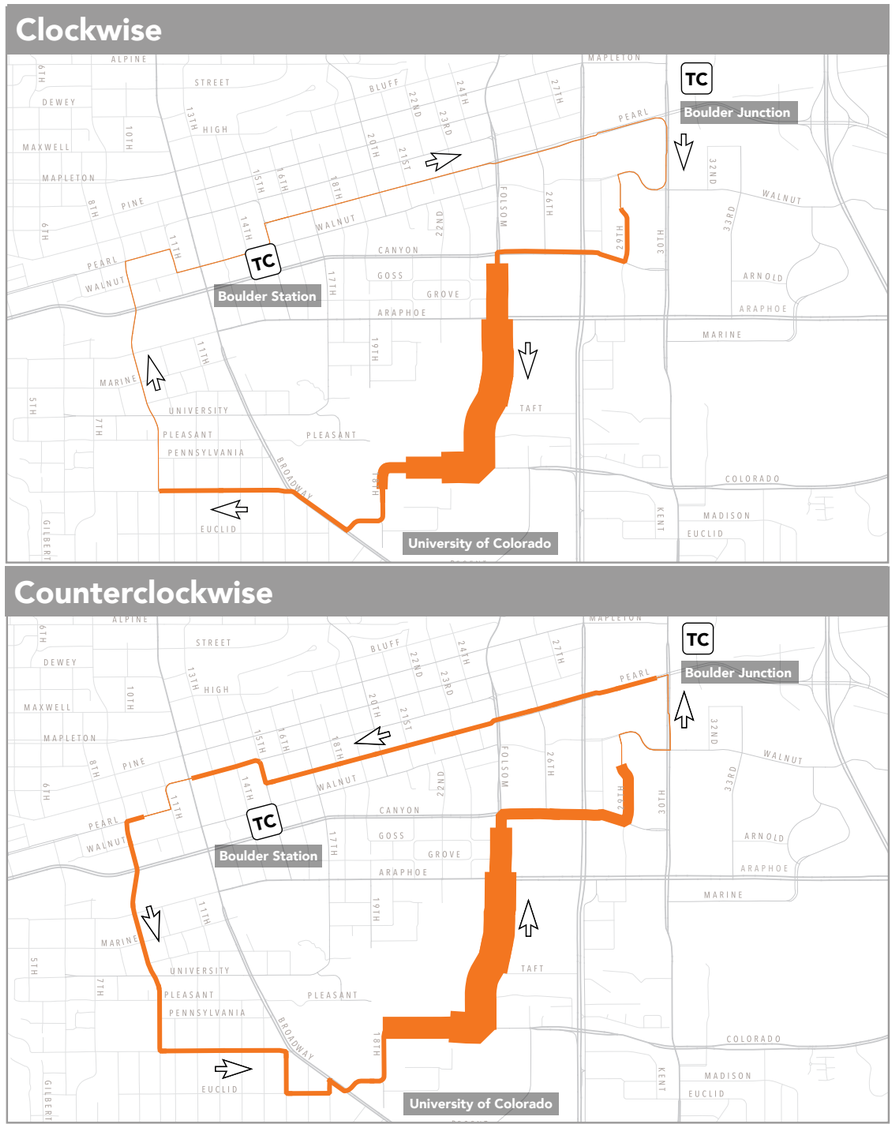
Ridership data also reveal that few people stay on the bus through the two points where it turns a "corner" of the roughly triangular route. The figure at right shows this: at points just west of downtown and just south of Boulder Junction, there are only 6-8 people on the bus in either direction, on an average weekday. A different type of data is required to understand the percentage of trips that go around these "corners," but it is likely very low.

This report poses three main questions:

- Why is HOP ridership low on two of the route's three segments? Why is ridership high on the third segment?
- Why are few people staying on the bus at it goes around the "corners"?
- What do these facts suggest about Boulder's future choices for the HOP?

The purpose of this report is to highlight the choices that the City faces for the HOP:

- How important is it that the HOP remains a loop?
- Should the HOP remain a standalone route as it was formed in 1994, or should it be integrated with the transit network that exists today?
- Of the HOP's current and potential mix of purposes, which are higher priorities?
  - » How important is it that the HOP contribute to meeting the City's climate goals?




## HOP Average Occupancy

Weekday average number of passengers on board between each pair of bus stops.

- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 17

Data source: April 2016 count of boardings and alightings on all transit vehicle trips on a Monday and Tuesday. For more information, see Appendix B.

Figure 1: This map shows the HOP's route, in varying thickness that indicates how full the buses are along the route. HOP buses are fullest between the 29th Street Mall and CU: ridership on the rest of the route is far lower. In places where the line is thinnest in both directions – downtown and at Boulder Junction – few people are riding around the "corners," and the segments between these corners can be evaluated as nearly separate routes.

## Travel Times

Transit loops generally struggle to compete with biking, walking or driving. This is because only their straight segments offer direct travel, but their straight segments are short. For short trips, people are very sensitive to waiting time, and cycling and walking become more appealing than waiting for the bus.

If we selected pairs of points along the HOP route at random, connecting about half of those pairs would require circuitous travel on the HOP route. Travelling between CU and downtown requires particularly circuitous travel.

The table at right shows average travel times between some important places along the HOP route, for transit, walking and biking. (Driving is faster for all of these trips, so it has been left out.) Were we to perform this analysis not just for three sample trips but for all bus stops along the HOP route, we would find that the HOP "wins" the race mostly for trips:

- Beginning and ending along the CU segment of the triangle (as illustrated at right),
- Beginning and ending along the Pearl Street segment.

In both of these cases, the path that the HOP travels is no more indirect than what someone would walk, bike or drive. For this reason, the HOP can compete well against other modes.

For trips to and from places that the HOP connects with an indirect, curved path (especially, from Pearl & Folsom to CU) other modes – walking, cycling or driving – are naturally much faster than the HOP.

## Loops

When you ask people to draw a transit route for their town, they will often draw a loop. They start by thinking about the various places they want to go. They often assume that transit will be infrequent, and therefore that any transferring would involve a long wait. Once they are focused on connecting many places, without any transfers, they naturally draw loops and other circuitous shapes. The loop seems like the simplest solution to the problem of how to connect many places that aren't  arranged in a line.

Unfortunately, hardly anyone wants to travel in circles. (The exception is when people are on vacation, which explains the origin of the word *tourist*: from *tour*, meaning *circle*.) People don't even like to travel in *half* circles if they can avoid it, but many trips on a loop require it.

Trips on the HOP that would require riding in a half-circle attract fewer riders; trips for which the HOP provides a reasonably direct path attract more riders.

One curious exception is trips between University Hill and Pearl Street. The HOP *does* provide a reasonably direct path between these streets, yet very few people ride around the northwest "corner" of the route (see the very thin orange line in Figure 1 on page 4). Why might this be?

This is probably due to two combined factors: the lower density of residences and businesses in the Hill (shown in maps starting on page 35) and the great deal of frequent transit just a few blocks from 9th Street, on Broadway (as shown in the map on the following page). The 9th Street segment of the HOP has the fewest people near any bus stop, and also the most transit competing for those few people's trips.

Most transit loops attract less ridership than the HOP, because:

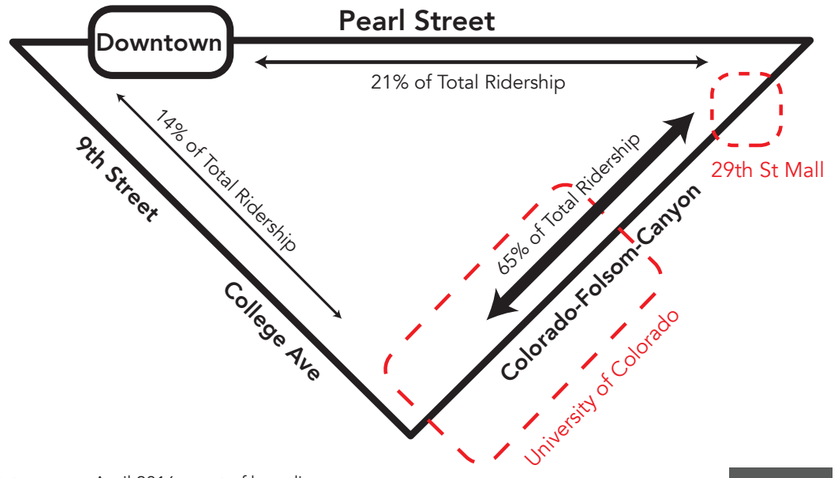
- Loops feel direct to passengers only for short trips...
- The shorter the transit trip, the more that *waiting time* affects total travel time, therefore...
- Loops must be *extremely frequent* if they are to attract high ridership.

Fortunately, the HOP is very frequent (on weekdays, it arrives every 9 minutes, on average). Because waits are short, it successfully competes for more trips than it otherwise would.

Loops work best when they are extremely frequent and do not compete with walking, as is the case for airport circulators. Loops also work well when they are not meant to attract many riders, such as in a very low-density, car-oriented areas where a long looping route can provide lifeline access, but is not expected to compete against other travel modes for very many people.

| From | To | Average midday travel time (in minutes) | | | | | |
|---|---|---|---|---|---|---|---|
| | | HOP | | | Walk | Bike | Other transit |
| | | *Avg. wait* | *Ride* | Total | | | |
| Pearl & 20th | Folsom & Arapahoe | *4.5* | *12* | 16.5 | 15 | 5 | 18.5 |
| Folsom & Arapahoe | College & Broadway | *4.5* | *10* | 14.5 | 23 | 11 | 25.5 |
| College & Broadway | Downtown Station | *4.5* | *11* | 15.5 | 20 | 13 | 7.5 |

Figure 2: This table shows the results of a travel time "race" for three potential trips (based on Google Maps estimates during the weekday midday). Driving is fastest for all of these trips; biking is second-fastest for two of them. The next "winner" is highlighted in teal, for each trip. Because the HOP is a loop, and takes people out-of-direction for many trips, it will struggle to compete with walking for short trips. Also, there is so much other frequent service on Broadway that any trip along Broadway is far faster by other routes than by the HOP.




Data source: April 2016 count of boardings and alightings on all transit vehicle trips on a Monday and Tuesday. For more information, see the Appendix.

Figure 3: The HOP runs in a loop, but it has the fewest people on it when it turns the "corners" of the route.  In this report, each of these segments is analyzed separately, because their performances – and, perhaps, their purposes – are so different

## Boulder's Transit Network

The map at right shows Boulder's entire local transit network, which is made up mostly of services provided by the Regional Transportation District (RTD). A few features of the Boulder network are worth pointing out explicitly:

- Boulder has a *frequent grid,* shown in red. Anyone located on a red line can go anywhere on another red line with a single short transfer. A frequent grid is a very powerful type of network, because it gives people the freedom to reach so much of their city, with short waits.
- When the HOP is on 9th Street, it is running just a few blocks away from Broadway, where many routes combine to offer even higher-frequency service. People between these two corridors could walk to either street, but they probably walk to Broadway to enjoy a shorter wait. The HOP and Broadway services are competing with one another for trips in this area.
- The HOP is the only service on Pearl Street, and the only frequent east-west grid element, north of Arapahoe.
- In this map, the private transportation operated by CU is shown in brown dashed lines. Though they are not shown in red, some of the CU routes are extremely frequent, and get such high ridership that CU uses double-length buses. They probably compete well against RTD services and the HOP (when school is in session). It seems likely that, for the amount of service that RTD, the City and CU are investing in this area, more ridership could be achieved at the same cost through more integrated network planning.

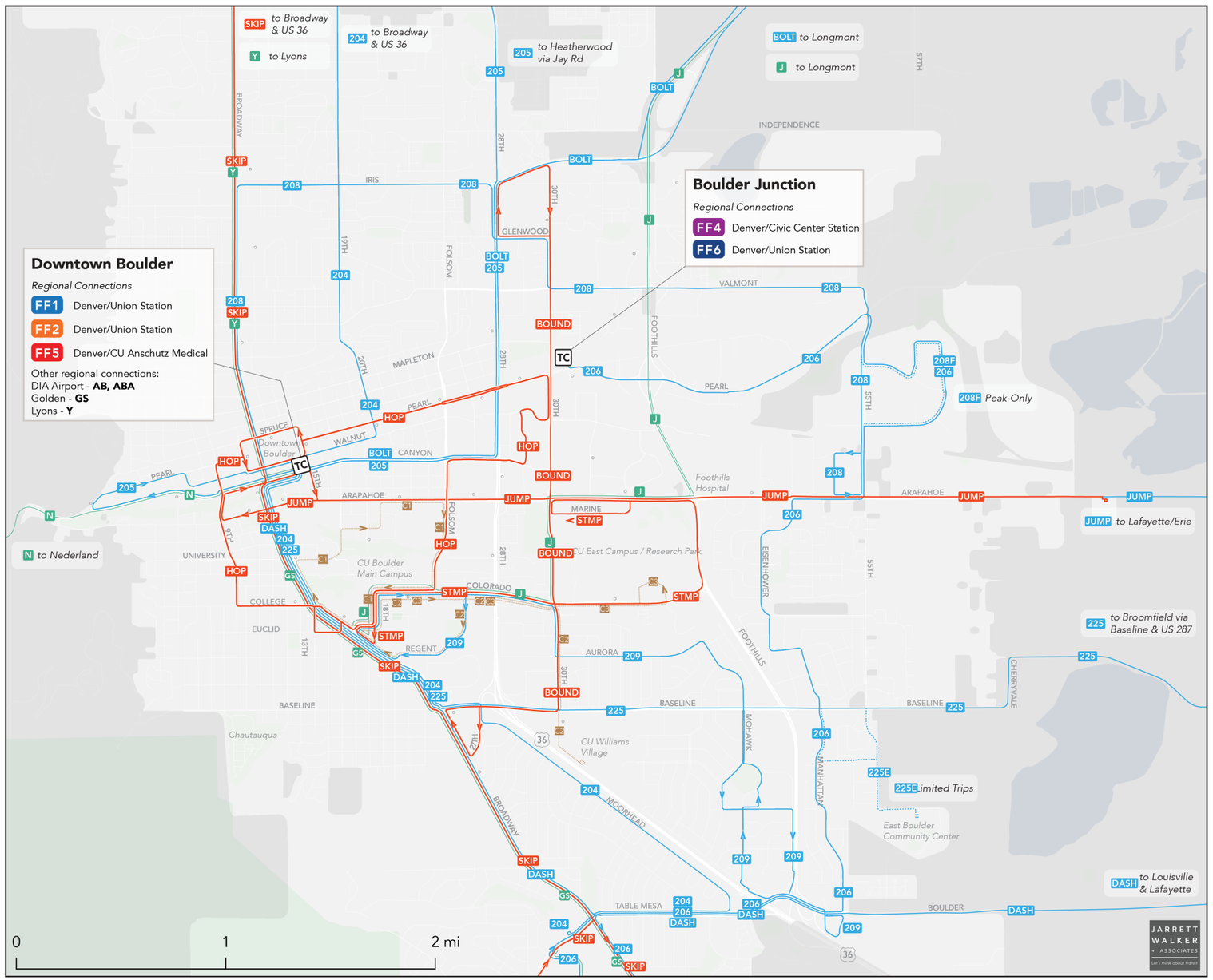



Figure 4: The HOP is the City's flagship transit service, but the City also pays for higher frequencies on other routes than RTD could justify providing on its own. As a result, Boulder is served by a large network of frequent services (shown in red), which includes – but is by no means limited to – the HOP.

## Boulder Junction and Pearl Street

It seems reasonable, based on the transit network map, to expect that the HOP would be used by many people to connect with local and regional routes, serving the "first/last mile" of their transit trips.

It is also reasonable to expect boardings around Pearl Street and Boulder Junction to be high. Boulder Junction has relatively high densities of jobs and activities, and is a regional transit station. Hotels, grocery stores and retail outlets like those around Pearl and 30th normally generate high boardings at nearby stops. The same is mostly true of Pearl Street.

Surprisingly, neither of these expectations is met :

- Few people are transferring to or from the HOP – just 9% of surveyed riders, as shown in the chart below. More people drive and park to access the HOP than transfer from another route.
- Boardings at or around Boulder Junction are only moderate, as shown in the map at right.

On a map of Boulder's transit network, it looks like the HOP should be providing a frequent grid connection between Broadway and 30th. In a productive frequent grid, there would be many people transferring to other routes at both ends of Pearl Street, but boardings and transfer data clearly indicate otherwise.

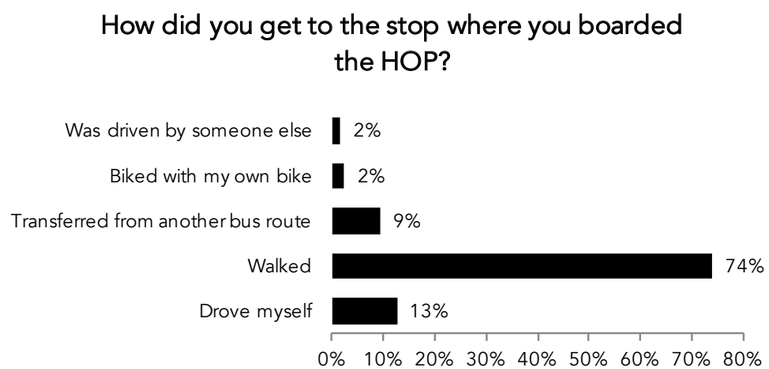
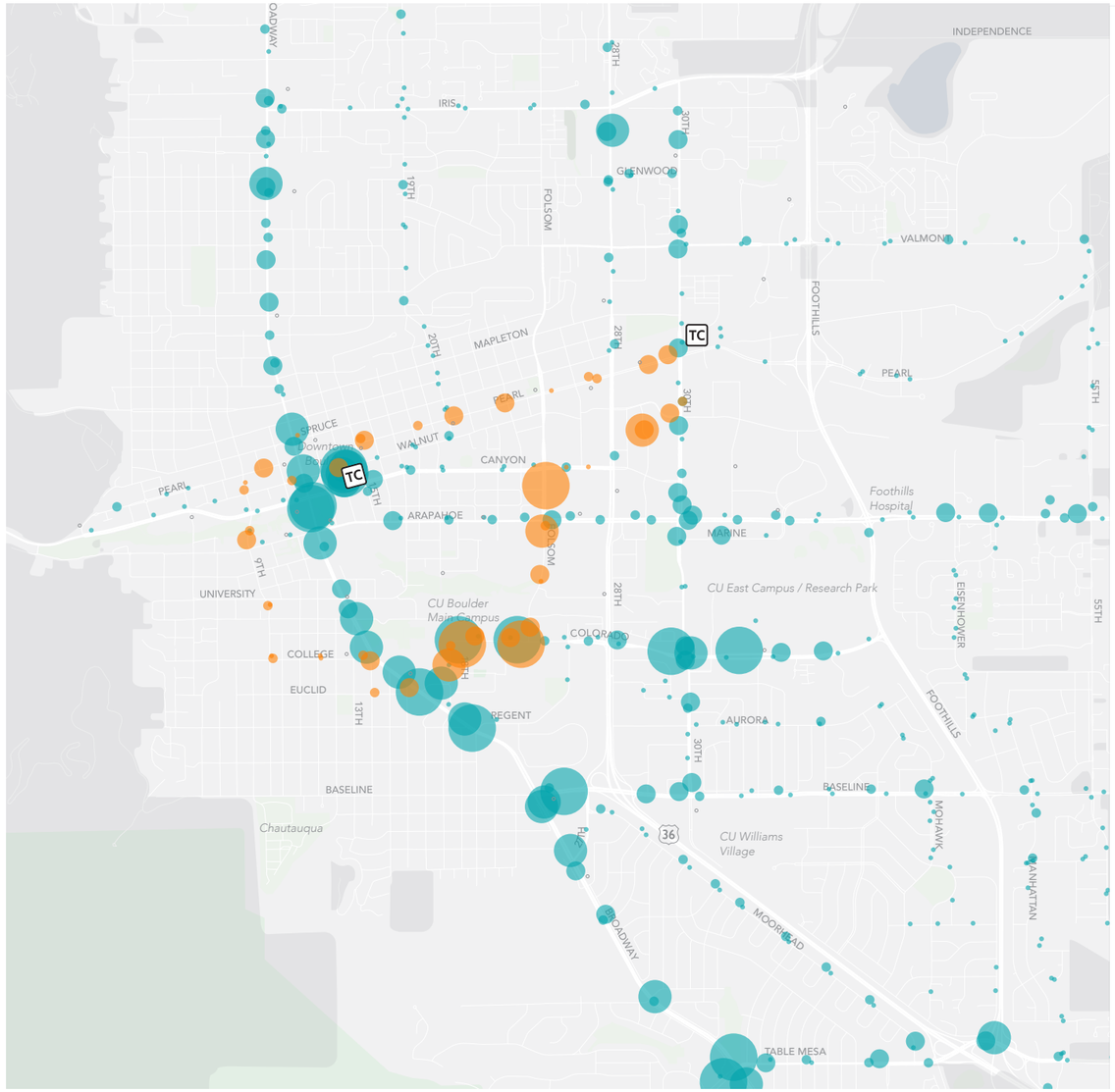



Figure 5: Few people are using the HOP to make "first/last mile" connections from other, longer-distance transit routes. More people park-and-ride the HOP (13%) than transfer to it from another route (9%). Data source: Transfer survey, implemented on a Wednesday morning in April 2016. For more information, see Appendix B.




## Transit Ridership

**Average Daily Boardings by Stop**

Total average number of people boarding the bus at each stop, across all local routes, for the HOP and other RTD routes.

- 0 - 15
- 15 - 50
- 50 - 150
- 150 - 300
- 300 - 1000

- HOP Boardings
- RTD Boardings

Data source: For the HOP, April 2016 count of boardings and alightings on all transit vehicle trips on a Monday and Tuesday. For more information, see the Appendix. Data for RTD routes is for January 2016.

Figure 6: Relative to boardings elsewhere on the Boulder transit network, boardings on the HOP (shown in orange) are high only on the CU segment. Boardings at the Downtown and Boulder Junction Transit Stations, and on Pearl Street (where the HOP is the only route) are surprisingly low.

Why would the HOP segment on Pearl Street not work as part of Boulder's frequent transit grid? The explanation surely involves multiple factors, which may include:

- Because the Pearl Street segment is the "flat-top" of the roughly triangular loop, a trip from Pearl Street to most other places on the loop will require out-of-direction travel. Only trips from Pearl Street to University Hill will feel reasonably direct and, as discussed in the previous section, University Hill has the lowest densities along the HOP route.
- The Boulder frequent transit grid is missing a north-south route around Folsom Street. The lack of this route means that the Pearl Street segment of the HOP can't be used to access CU (at least, not without a long ride around the loop's corners). For someone starting downtown, the faster way to get to different parts of campus or campus-adjacent housing will be via frequent transit on Broadway or Arapahoe, or via walking or cycling.
- To a certain degree, frequent service on Arapahoe and the multiple infrequent routes on Canyon may be competing with the HOP. Because these three east-west corridors are within walking distance of one another, they are splitting east-west ridership potential among them.
- Because the HOP is only useful for very short trips, anyone traveling beyond Pearl & 30th will walk to Canyon or Arapahoe to catch a transit route that takes them farther.
- Bike share stations are dense in this part of the city and east-west trips are fairly flat. This may make cycling particularly easy and fast, compared to riding the HOP, for many trips and many people.
- Transferring to the HOP from regional and local routes that stop at Boulder Junction requires a long (approximately 8-minute walk).

While the HOP is the city's flagship route, and Pearl Street is the city's main street, the HOP seems barely relevant to Pearl Street transportation today. Most of the factors described above relate not just to the HOP but to the Boulder transit *network.* This means that making *any* transit service relevant on Pearl Street requires thinking about the usefulness of the entire network around Pearl Street.

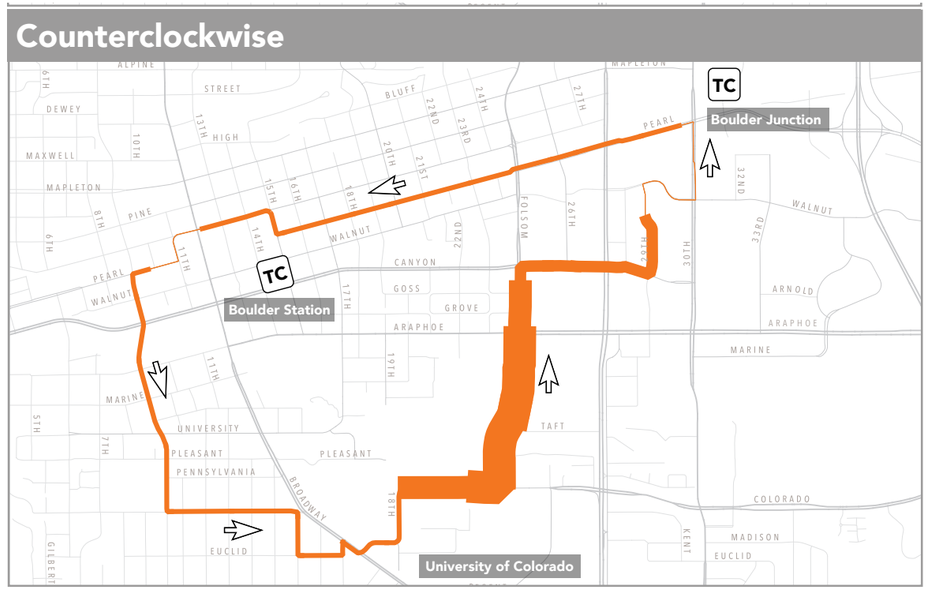



Figure 7: In this diagram, the average fullness of HOP buses (in the counter-clockwise direction) is represented by the thickness of the orange line. Ridership is low on Pearl Street, but it is lowest on the segments that connect Pearl Street to CU and Pearl Street to University Hill, likely because such trips require so much out-of-direction travel on the HOP.

## University-Related Ridership

It is generally true that high-ridership transit is ridden by many different kinds of people, for many different types of trips, at different times of day and in different directions. In other words, high ridership transit arises from *diversity* rather than *specialization*.

The biggest exception to this principle is the large public university. Universities offer a perfect storm of transit ridership potential:

- Large numbers of people in living in dense housing and working/studying in dense educational facilities.
- Many of them on limited incomes and without cars.
- Constrained and priced parking on campus.
- Travel happening throughout the day (not just at rush-hours).
- Bulk transit fare purchases (e.g. the CU Pass).

This is why CU, like most large universities, finds it worthwhile to run highly specialized transit routes, just for CU students and staff. This is also why, despite their narrow specialization around the needs of CU, these routes attract such high ridership.

It is also no surprise that so much of the HOP's ridership relates to CU. This would be obvious to anyone who has spent time in Boulder, but the data confirms it.

In the chart above at right, we can see how many of the people boarding the HOP on a weekday (during the academic year) pay with a CU Pass. (This pass is purchased by the student body, paid for by fees that they collect from every individual student.) About 4 in 6 riders use a CU Pass.

The next most common fare type is the ECO Pass, which Boulder residents or workers can purchase in self-organized groups, but only about 1 in 6 riders use an ECO Pass. Even fewer use an RTD pass or transfer, and hardly anyone pays cash.

The seasonality of CU ridership is clear in the chart at right on the bottom. The number of fares collected (i.e. the number of people boarding) drops precipitously when CU is not in session.

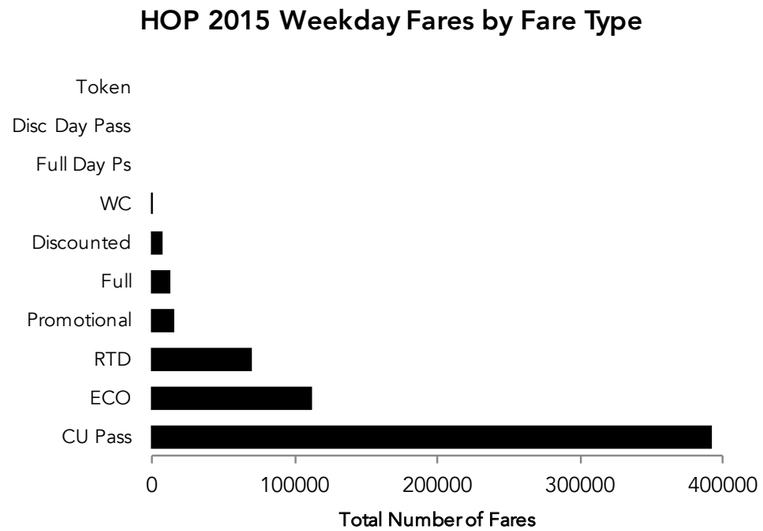



Figure 8: We learn something about *who* is riding the HOP by examining fares. By far, most riders pay with a CU Pass. Data source: VIA farebox records for 2015.

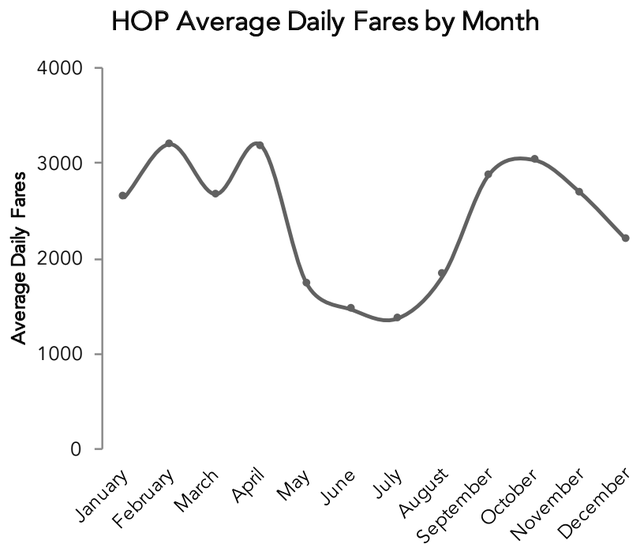



Figure 9: Ridership on the HOP is very seasonal. The peaks, during the academic year, are more than twice as high as the valley, which is during the summer. Data source: VIA farebox records for 2015.

## Ridership Trends

Total ridership on the HOP has declined very slowly over the past 20 years. While the decline is slow, there are reasons to be concerned:

- The City has been steadily increasing the amount of service provided on the HOP. Thus ridership *relative to cost* has been falling faster than sheer ridership. The graph in Figure 10 shows the decline in boardings despite the increase in service.
- The City has more aggressive programs in place to shift away from automobile travel, and towards transit and other modes, than it did 20 years ago. The City's future targets for non-drive-alone rates are high. Despite ambitious goals and programs, ridership on the HOP has not increased.
- Ridership is declining even as the number of people living or working in Boulder is slowly increasing. We can think of ridership relative to residents or jobs as measures of the HOP's *relevance* to city life: "*How likely is it that someone I know finds the HOP useful?*" Relevance has gone down.

An additional concerning trend is that the HOP's fleet is aging faster than it is being replaced. As a result, maintenance breakdowns are becoming more common; the time required to restore service after a breakdown is getting longer (because fewer usable spares are available); and the fleet is no longer big enough to maintain the HOP's advertised frequency (7-10 minutes, weekday daytimes) at the current operating speeds.

On a final note, there may be a fundamental mismatch between the City's development trends and the historic shape of the HOP.

A circular route will, by definition, always be turning away from connections. It cannot be lengthened when a city grows or changes shape. It will only be useful for short trips, within or near the circle. Expanding a circle is extremely expensive, because reaching out an additional 1 mile requires adding 2 miles to the route. The HOP loop will always be limited in these basic geometric ways.

Meanwhile, Boulder, like many cities, is developing more commercially and institutionally than residentially. This means that the distances people must commute into and across the city will naturally increase.

For transit to maintain or improve its relevance, it must be useful to large numbers of people for longer trips (especially as cycling becomes more attractive).

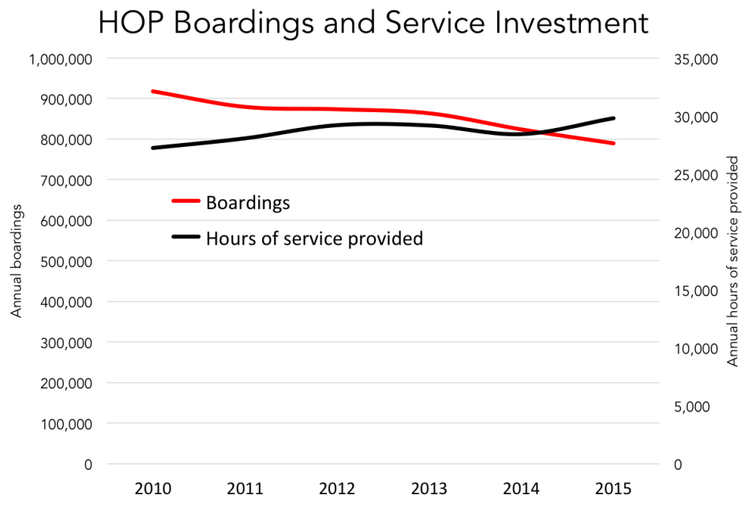



Figure 10: Ridership has slowly declined over the years, even as the HOP's funding partners have added service to maintain its high frequency. Data source: VIA.

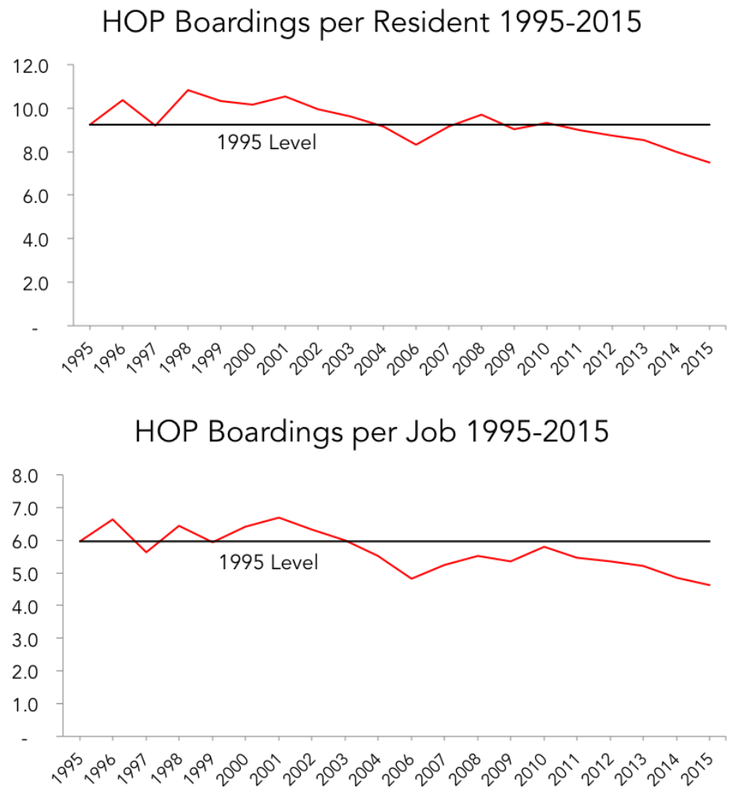



Figure 11: When measured relative to the number of residents or jobs in Boulder, the decrease in annual HOP boardings looks a bit steeper. In essence, its relevance to the life of the city has been declining. Data sources: VIA (boardings), CO Dept. of Local Affairs (residents); Bureau of Labor Statistics (jobs).

# 2 Transit Service Analysis

## Introduction

HOP service began in October of 1994, and has been running since then without major changes to where it goes or when it goes. It is a two-way loop around the center of Boulder. While the City, the Regional Transit District (RTD) and CU fund HOP service, VIA Mobility Services (a local non-profit) is contracted to operate the HOP for the City.

Ridership grew from 1994–2003, but has been flat or falling gradually ever since.

The City advertises HOP frequencies of 7–10 minutes during daytimes on weekdays, during the academic year. To deliver this frequency, VIA runs 8 buses around the loop (4 in each direction). (RTD, on its website, describes the HOP as offering 9–15 minute frequencies.)

Frequencies are intentionally lower in the evenings, on weekends, and on weekdays when school is not in session.

**The advertised weekday frequency of the HOP is 7-10 minutes. This is achieved only 2/3 of the time.**

The slower buses travel, the more of them are needed in order to deliver the same frequency to waiting passengers. As the HOP has slowed down over the years, providing its original frequency has become more expensive and, without a large increase in funding, more difficult. An analysis of recent arrival time data shows that only 66% of clockwise buses, and 57% of counter-clockwise buses, maintained a frequency of 10 minutes or less.

For the HOP to offer 7–10 minute frequency more reliably, as advertised, would require one or more changes:

- Additional operating funds would be needed, to put more drivers and buses on the route at the same time;
- Additional capital funds would be needed, to buy more buses, because the current fleet is beyond its useful life;
- Some increase in frequency might be achievable if the HOP service were sped up considerably, using multiple strategies (such as transit priority at intersections, bus-only lanes, elimination of cash fares, or wider stop spacing); and/or
- The route would need to be shortened.

## Boulder's Transit Network

The map on the following page shows Boulder's entire transit network, with routes color-coded by frequency. (Regional connections provided by the Flatiron Flyer and other routes are named at the transit station where they stop.) Most routes are operated by the RTD.

A few features of the Boulder network are worth pointing out explicitly:

- Boulder has a *frequent grid,* shown in red, much of which is called the Community Transit Network (CTN). Anyone located on a red line can go anywhere on another red line with a single short transfer. A frequent grid is a very powerful type of network, because it gives people the freedom to reach so much of their city, with short waits. The HOP is part of the
- When the HOP is on 9th Street, it is running just a few blocks away from Broadway, where many routes combine to offer even higher-frequency service. People between these two corridors could walk to either street, but they probably walk to Broadway to enjoy a shorter wait. The HOP and Broadway services are competing with one another for trips in this area.
- The HOP is the only service on Pearl Street, and the only frequent east-west grid element, north of Arapahoe.
- In map on the following page, the private transportation operated by CU is shown in brown dashed lines. Routes C1 and C2 serve the housing areas at Athens Court and Williams Village; Route C3 connects the main and east campuses. Most of this service only exists during the academic year. However, some of it is very frequent, and attracts such high ridership that CU uses articulated (double-length) buses to handle demand.

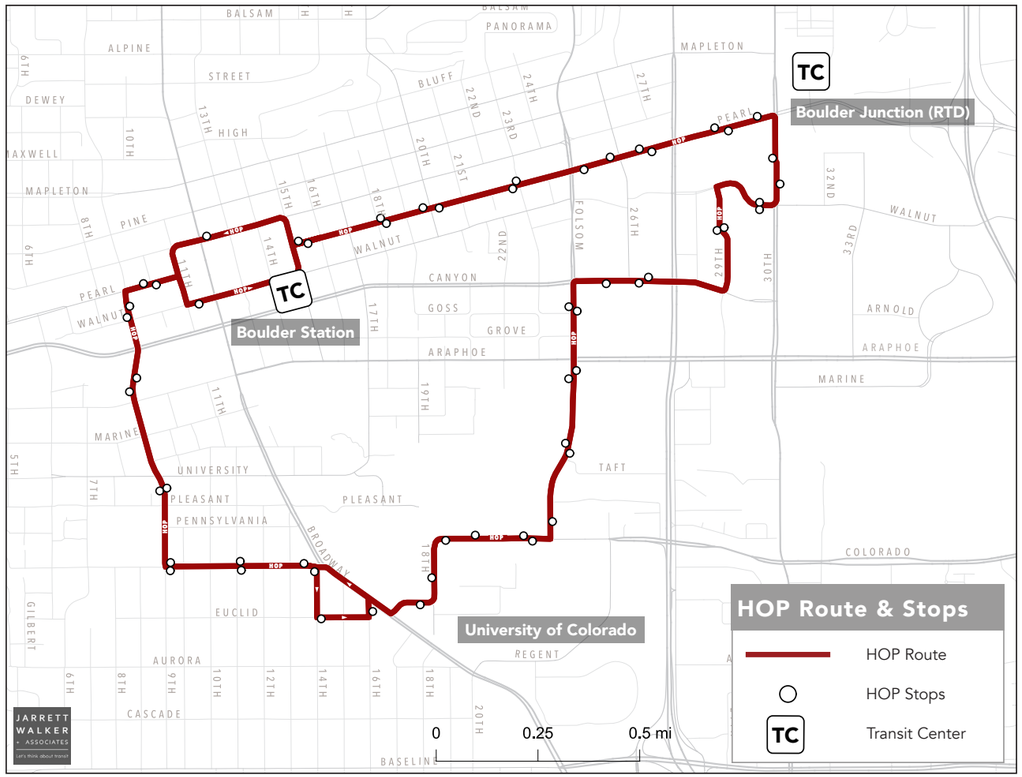
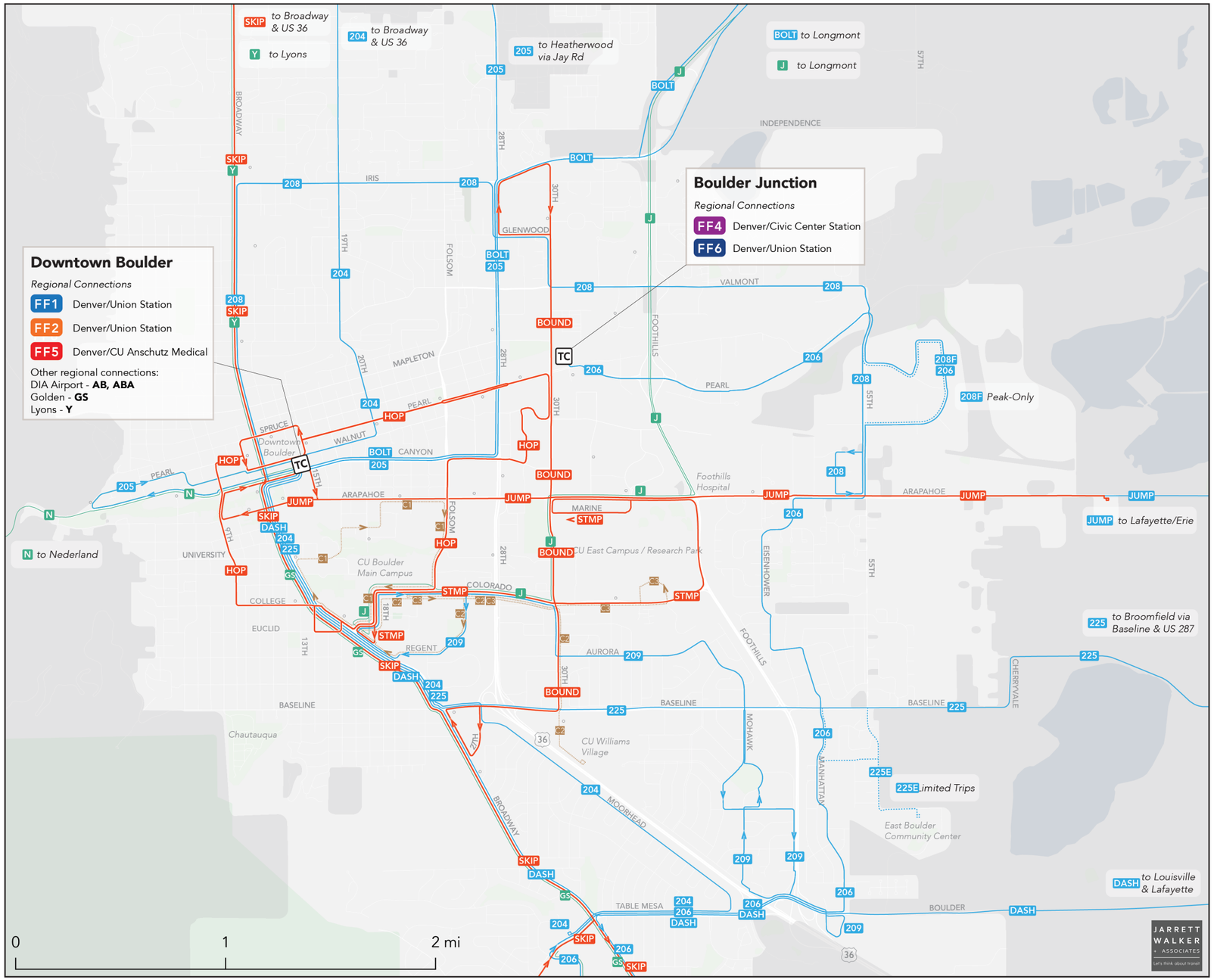



Figure 12: The City of Boulder's HOP circulator was created in 1995, and has been largely unchanged since then. It was the first route in the Community Transit Network, which is partially funded by the City and has since grown.

Figure 13: This map shows the entire Boulder transit network, with routes color-coded by frequency.

Boulder has a large frequent grid; people can travel from anywhere on a red line to anywhere on another red line with a single, fast transfer.

RTD likely could not justify providing high frequencies on some of these routes, so the City of Boulder pays RTD to provide higher frequencies. Thus while the HOP is the City's best-known transit initiative, City leadership is also partly responsible for Boulder's frequent grid, which serves an even larger part of the city.




## Boulder Transit Network

Showing local and regional RTD, City of Boulder, and CU Boulder Routes.

### Route Prevailing Midday Frequency

The prevailing midday frequency is the typical interval in minutes between succeeding buses at each stop along a transit route.

- 0-15 minutes
- 16-45 minutes (typically 30 minutes)
- Regional routes (typically longer than 60 minute frequency, or limited trips)
- CU routes
- One-way service
- Route continues at lower frequency (turnback)

### CU Routes

These routes are operated by CU and are only open to students and others affiliated with the university.

- **C1** Athens Court Shuttle
  *AM/PM only. Every 15 minutes.*
- **C2** Will Vill (Brown Line)
  *Fall & Spring only. Every 5 minutes.*
- **C3** Discovery Express
  *Every 15 minutes.*

- Bike Share Station
- Natural Area
- Water
- Boulder City Limits

## Frequency is Freedom

In transit conversations there is always a great focus on where transit is provided, but unfortunately little concern about when it is provided. The "when" of transit service is described as frequency (how many minutes between each bus) and span (how many hours a day and days a week it runs). Low frequencies and short spans are one of the main ways that transit fails to be useful, because it means service is simply not there when the customer needs to travel.

Even though Google Maps or an app on a phone can be consulted for directions, frequent transit service is effective at attracting ridership because it has the simplicity of a road – you can use it anytime you need. Frequent service allows someone to maintain a map of the transit system much like a road map, in that no schedule is needed. Frequent service:

- Reduces waiting time (and thus overall travel time).
- Improves reliability for the customer, because if something happens to your bus, another one is always coming soon.
- Makes transit service more legible, and allows for spontaneity, by reducing the need to consult a schedule.
- Increases capacity (moving more people, with less crowding) on busy routes or at busy times.

Many people assume that today, with real-time information and smartphones, nobody needs to wait for a bus anymore, therefore, frequency doesn't matter. If a bus only comes once an hour, that's fine, because your phone will tell you when it is a few minutes away and you should start walking.

Despite all these new technologies, frequency still matters enormously because:

- *Waiting doesn't just happen at the start of your ride, it also happens at the end.* You may not need to leave the house much before your departure, but if your bus is infrequent and the schedule doesn't happen to line up perfectly with your desired arrival time, you have to choose between being very early or too late.
- *Many of the places we go don't let us hang out until our bus's arrival is imminent.* We can easily do this when leaving home, but it is more awkward when leaving a restaurant, a workplace or when running an errand.
- *Real-time arrival information doesn't make the bus more reliable, but frequency does.* Your smartphone can tell you when your bus is arriving, but it cannot prevent your bus from having a problem and being severely delayed, or not showing up at all. Only frequency – which means that another bus is always coming soon – can offer this kind of reliability.

Boulder's network of frequent routes is delivering not just short travel times but *reliably* short travel times. In exchange for transferring, people have the freedom to travel when they want, quickly and reliably, to a huge proportion of the opportunities the city has to offer.

## Balancing Flexibility and Predictability

The HOP is a "deviated fixed route." This means that, upon request, it will leave its route and go to drop someone off or pick someone up within 3/4 mile of the route. In this sense, the HOP is flexible and responsive to individual needs.

While a "flexible" route sounds appealing, because each of us appreciates when special accommodations are made for us, flexibility always trades off against reliability and predictability. A route that is responsive to our individual needs cannot be there for us all the time, reliably, because it will sometimes be off responding to *other people's* individual needs.

Flexible transit is responsive but very expensive per passenger. While a fixed route is considered to have low ridership if it attracts 10 passengers per hour, a purely flexible service (like dial-a-ride) maxes-out at 3-4 passengers per hour. The vehicle that comes to your door is intrinsically low-efficiency. (Even Uber and Lyft have discovered the value of rigidity, offering passengers a discount if they wait at a fixed stop in many cities.)

There is a geometric logic to rigid, fixed transit: when you connect places that many people want to go, along a fast, direct path, the resulting service is both efficient to provide *and* useful to large numbers of people.

This is why transit agencies often deploy flexible services in low-demand but growing markets, and then replace them with fixed routes once demand grows beyond what flexible services can handle.

A "deviated fixed route" like the HOP is an interim step, but its responsiveness to individual requests will put a downward pressure on its ridership and productivity, because a bus full of passengers will be delayed and annoyed by a deviation. (On the HOP, deviations are allowed at any time, but they are encouraged only at night.)

## Balancing Ridership and Coverage

Most conversations about transit arrive, sooner or later, at a basic conflict between transit's major goals: maximize ridership, or provide coverage? This will arise in planning for the HOP, because ridership on one separable segment is so much higher than on the others.

Maximizing ridership serves a number of values, such as:

- Reducing driving, and with it pollution, carbon emissions, noise, parking requirements, and other negative impacts.
- Supporting compact urban development without an accompanying increase in auto traffic, congestion and parking demand.
- Reducing household transportation costs.
- Improving access to jobs for large numbers of workers.
- Reducing subsidy per passenger, since high ridership transit divides its operating costs over a larger number of passengers.

There are other goals for transit, that do *not* depend on high ridership:

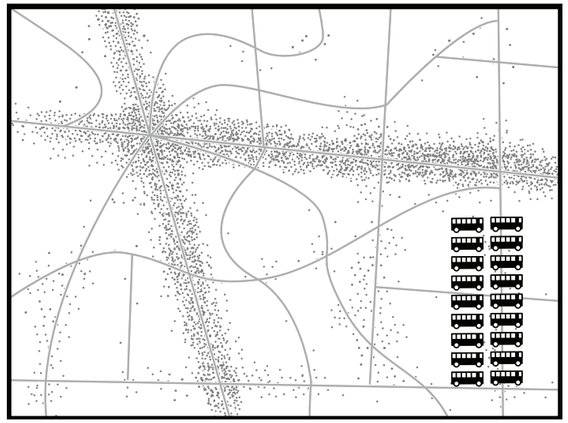
- Providing access to transit to a large number of people or places. (Access is valued whether or not the transit is actually *used*.)
- Providing service close to those who pay for it (e.g. through taxes).
- Making sure that people with severe needs for transit (due to income, age or disability) have access, no matter where they live.

These two sets of goals can be thought of as "ridership goals" and "coverage goals." Ridership goals are only achieved when ridership is high relative to cost. Coverage goals, on the other hand, are served through the presence and availability of transit, whether or not people ride it.

It is important that we think clearly about the difference between ridership and coverage goals because, for simple mathematical reasons, they are in conflict. If a transit agency wants to do more of one, it must (within a fixed budget) do less of the other. This conflict is illustrated on the following page.

In the fictional town illustrated at right, the little dots are dwellings and commercial buildings and other land uses. The lines are roads. Most of the activity in the town is concentrated around a few roads, as in most towns.

A transit agency pursuing only a ridership goal would run all of its buses on the streets where there are large numbers of people, walking to transit stops is easy, and where they can run straight routes that feel direct and

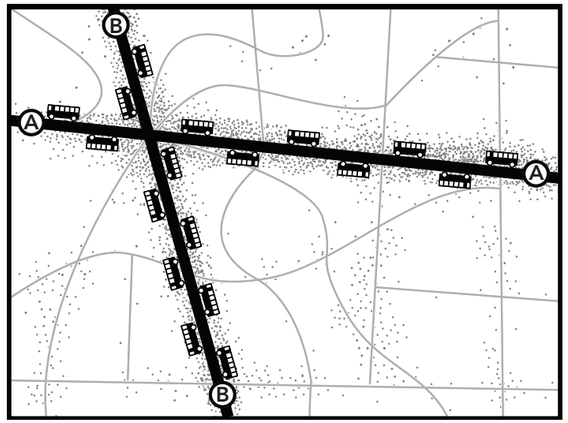


Imagine you are the transit planner for this fictional town. The dots scattered around the map are people and jobs; the streets shown are ones on which transit can be operated. The buses are the resources the town has to run transit.

Before you can plan transit routes, you must first decide what you want transit to do.

### Ridership Goal

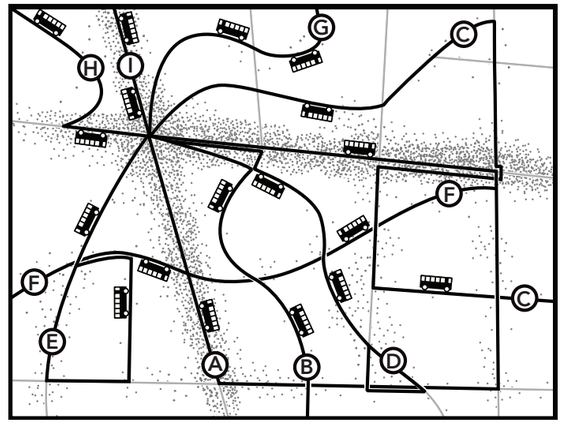
*"Think like a business"*




This transit network is designed to generate high ridership as efficiently as possible. The transit agency has thought like a business, investing its resources only into the best transit markets.

### Coverage Goal

*"Access for all"*




This network is designed to provide some access to the transit system for all people. The transit agency has divided its resources among many routes throughout the town, none very frequent.

Figure 14: In any city, within a budget of any size, ridership and coverage goals must be traded-off against one another. When budgets are bigger, the trade-off becomes easier, but it never goes away.

fast to customers. This would result in a network like the one at bottom-left.

If the town were pursuing only a coverage goal, on the other hand, the transit agency would spread out services so that every street had some bus service, as in the network at bottom-right. As a result, all routes would be infrequent, even those on the main roads.

In these two scenarios, the town is using the same number of buses. These two networks cost the same amount to operate, but they deliver very different outcomes.

On a fixed budget, designing transit for ridership or coverage is a zero sum game. In the networks in Figure 14, each bus that the transit agency runs down a main road, to provide higher frequency service there, is not running on the neighborhood streets, providing coverage, and vice versa. While an agency can pursue ridership and provide coverage within the same budget, it cannot do both with the same dollar. The more it does of one, the less it does of the other.

Fortunately, this is not a binary choice: with any given budget, a community can decide how much to spend maximizing ridership, and how much to spend providing coverage in low-ridership places. All transit providers pick a point on the spectrum between maximizing these goals.

How to optimize and balance ridership and coverage goals is not a technical question; it is one of values. It relates directly to the needs and desires of the community. With values questions, there is no single correct answer, and reasonable people may disagree about the optimal balance.

# 3 Performance Analysis

## Ridership

In this report, the number of boardings on the HOP is used to describe its ridership. (Keep in mind that when people use a transit network to make a trip involving a transfer, they show up in the data as two separate boardings.) This ridership data is used to visualize, analyze and think about both trends over time and ridership across geographic space.

### Total Ridership

The graph at top, in Figure 15, reveals that ridership has been slowly declining since the service was established in 1995.

### Relevance

Comparing ridership to the Boulder residential and worker populations gives us a sense of how relevant the HOP is likely to be to anyone who lives or works in Boulder.

As shown in the graphs in the middle and at the bottom of Figure 15, the HOP's relevance has been declining slightly faster than total boardings. HOP boardings have not kept up with residential and, to a greater degree, job development.

### Ridership Relative to Cost (Productivity)

When people want transit to "maximize ridership," this implies that they want service concentrated where the most ridership can be achieved relative to cost.

In transit, the major cost is the human driver, and that cost is tied to hours work (as opposed to miles driven). (This is why smaller buses generally do not cost less to operate: buses require one driver, whether they are big or small.) A simple and accurate way to represent cost, then, is simply the hours of service purchased by the City. Ridership per hour is also called "productivity."

The graph in Figure 16 shows that while ridership has declined, the annual investment in HOP service hours has increased. Thus ridership per hour, or "bang for buck," has dropped even more than total ridership.

In most cities, more frequent routes are more productive. This is both a "chicken and egg" effect: while transit agencies reward higher ridership with more frequency, more frequent routes also attract more ridership for each additional hour of cost that a higher frequency requires. Among Boulder's five frequent, local routes (highlighted in red in Figure 17) the HOP is the third most productive.

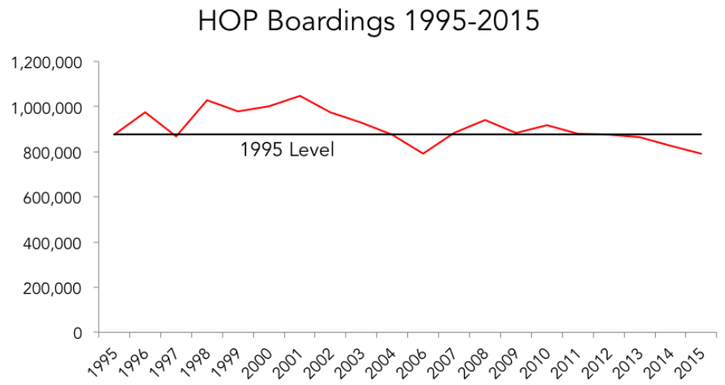



Figure 15: The chance that a Boulder resident or worker uses the HOP has decreased by 20-30% since the 90's. Data sources: VIA (boardings), CO Dept. of Local Affairs (residents); Bureau of Labor Statistics (jobs).

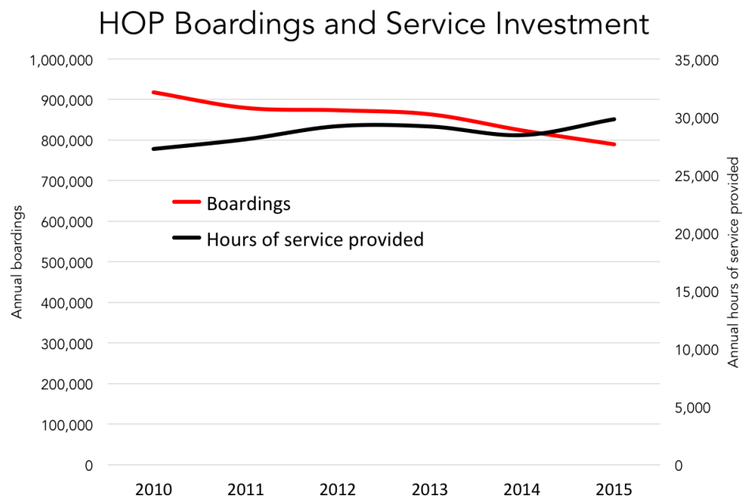



Figure 16: Ridership has slowly declined over the years, even as the City has added service to the HOP. Ridership relative to cost, "productivity," has therefore been declining even faster. Data source: VIA.

| Local Route | Productivity (boardings per hour) (2014) | Mainline frequency (weekday midday) |
|---|---|---|
| Skip | 44.3 | 10 minutes |
| Bound | 43.9 | 15 minutes |
| Dash | 30.5 | 30 minutes |
| Hop | 29.0 | 9 minutes |
| Stampede | 28.6 | 15 minutes |
| 208 | 24.7 | 30 minutes |
| 205 | 22.8 | 30 minutes |
| 209 | 20.7 | 30 minutes |
| 204 | 20.4 | 30 minutes |
| 225 | 18.0 | 30 minutes |
| Jump | 17.1 | 15 minutes |
| 206 | 16.4 | 30 minutes |

Figure 17: In this table, local Boulder routes are ranked based on their productivity (boardings per hour of service provided). Among frequent routes (every 15 minutes or better), the HOP ranks third out of five. Data sources: HOP 2014 farebox data, RTD 2014 Performance Report, RTD schedules 2016.

## HOP Ridership by Stop

In April 2016, counts of everyone boarding and alighting from the HOP were collected for all trips, on a Monday and Tuesday.

The resulting estimate of average weekday boardings per stop is shown in Figure 18. (For more information about data analysis, see Appendix B.) Keep in mind that only boardings are displayed on this map (the two colors represent the two directions of travel). Yet nearly every boarding represents an alighting on the reverse trip.

High ridership on the segment between 29th Street Mall and the central area of the CU campus is immediately obvious – the area enclosed by the dotted black line makes up approximately 65% of the average daily boardings on the HOP, and contains all of the highest ridership stops.

The busiest stops on the route are the clockwise, southbound stops from 29th Street Mall to Colorado along Folsom, and the counterclockwise (northbound) stops along Folsom and inside CU. On other parts of the HOP route, boardings are much lower.

It is not surprising that boardings would be low in University Hill. The number of residents, jobs and destinations near any given HOP stop is much lower on 9th Avenue than on most other parts of the route. (Maps of residential and job density, shown starting on page 35, make this clear.) In addition, service on nearby Broadway is so incredibly frequent (as shown in the network map on page 13) that many people's trips will be faster if they walk to Broadway and get a very short wait there.

It is somewhat surprising that boardings are as low as they are near the Downtown and Boulder Junction Transit Stations, and on Pearl Street. These are dense places with many activities and jobs. The HOP is the only frequent connection between them, and the only service on Pearl Street. On a frequent grid, like the one in Boulder, one would expect high boardings wherever two red lines (frequent routes) cross.

Why would the HOP segment on Pearl Street not work as part of Boulder's frequent transit grid? The explanation surely involves multiple factors, which may include:

- Very effective competition from cycling. Bike share stations are dense in this part of the city and east-west trips are fairly flat.
- For trips to and from downtown, anyone traveling from the denser south part of the city (around 30th) will be better off transferring at Arapahoe than continuing far north and transferring to the HOP.
- Transferring to the HOP from regional and local routes that stop at Boulder Junction requires a long walk, more than 1/4 mile (as shown in Figure 29 on page 26).

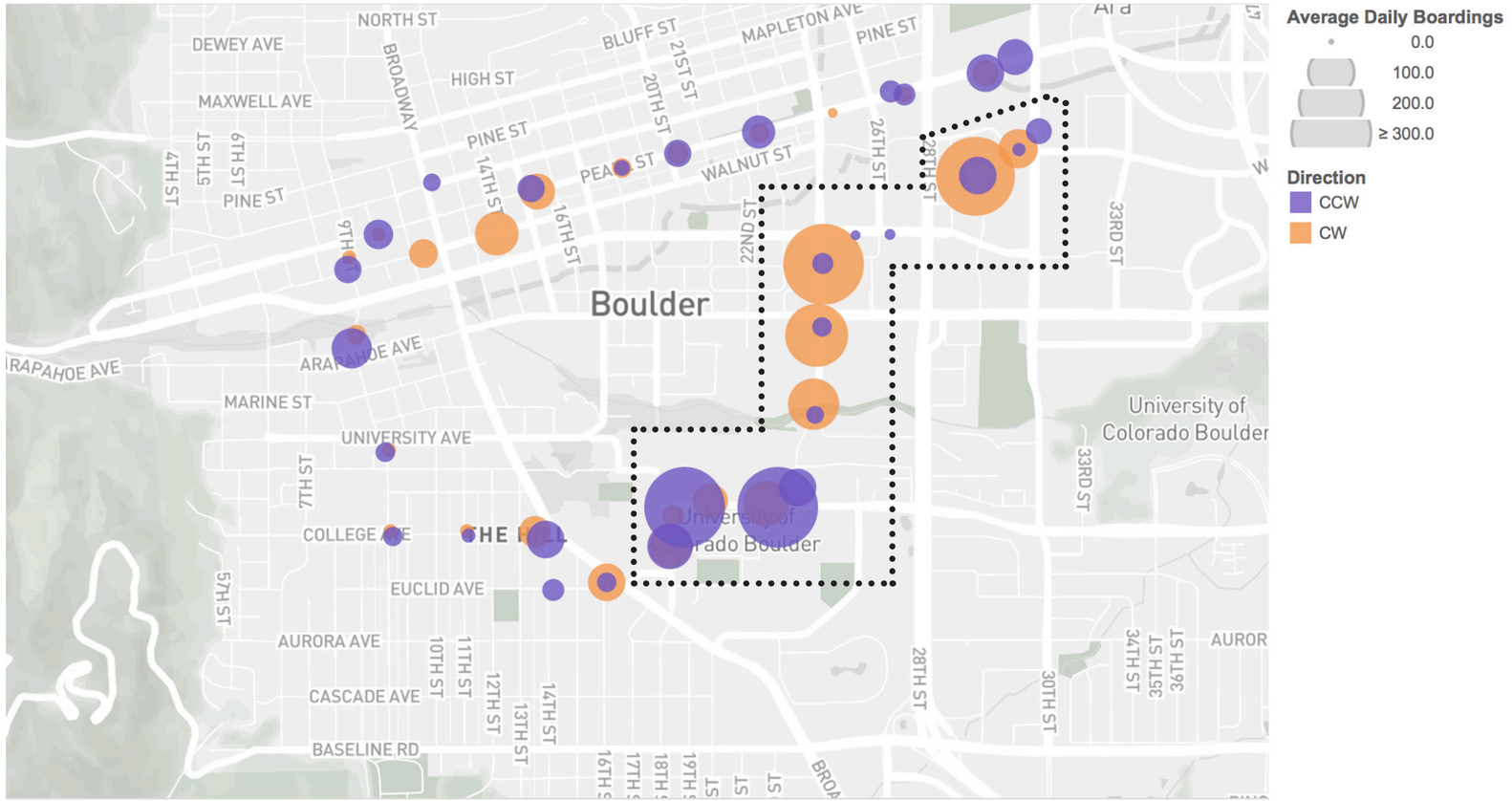



Figure 18: Weekday boardings at each bus stop, in the HOP's two directions (clockwise and counter-clockwise). Data source: April 2016 count of all boardings on a Monday and Tuesday.

## Network Ridership by Stop

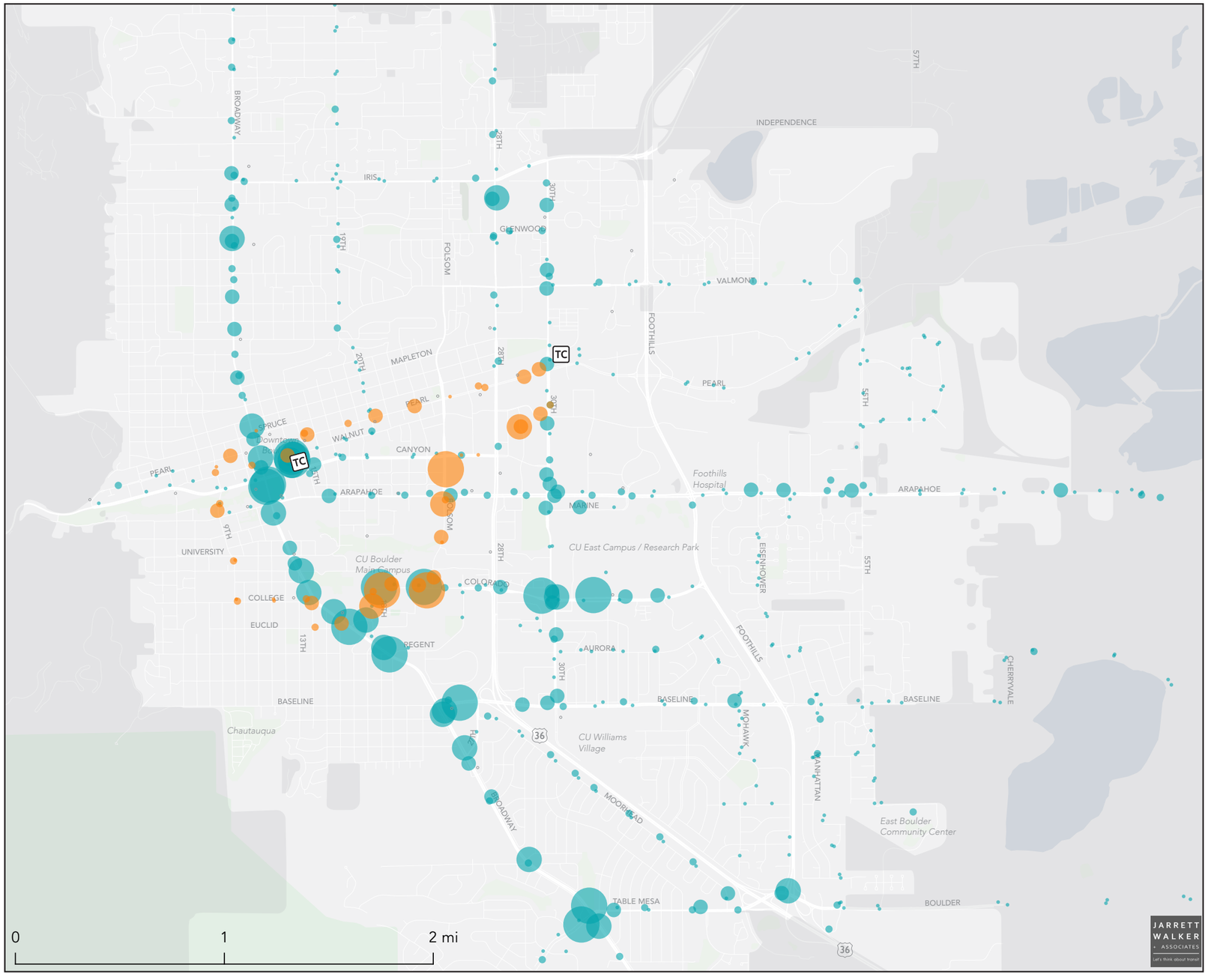
The map on the following page shows boardings by stop not only for the HOP, but also for all other local transit routes. (Boardings on intercity routes, like the Flatiron Flyer, are not included.)

In this grander scheme, the HOP's boardings around CU campus and student housing are within the top cohort citywide. However, many other corridors appear as significant, especially Broadway and Colorado.

Figure 19: On this map, each RTD and HOP bus stop is shown as a dot, scaled based on its average daily boardings.

The bus stops in the city that attract the most boardings per day are on Broadway, Colorado and Folsom.

This map does not show boardings on CU shuttles, the Night HOP (funded by CU), or on intercity routes (such as the Flatiron Flyers).




## Transit Ridership

**Average Daily Boardings by Stop**

Total average number of people boarding the bus at each stop, across all local routes, for the HOP and other RTD routes.

- 0 - 15
- 15 - 50
- 50 - 150
- 150 - 300
- 300 - 1000

HOP Boardings

RTD Boardings

Data source: For the HOP, April 2016 count of boardings and alightings on all transit vehicle trips on a Monday and Tuesday. For more information, see the Appendix. Data for RTD routes is for January 2016.

Natural Area

Water

Boulder City Limits

## Ridership by Time of Day

The HOP's daily pattern of demand is revealed when boardings are graphed for each hour of the day, as in the charts at right.

The image at top, Figure 20, shows the average number of boardings on the entire HOP route. Clockwise boardings are the orange line, and counter-clockwise boardings are the purple line. Ridership is higher in the clockwise direction in the morning and midday, and higher in the counter-clockwise direction in the afternoon.

The reason for this directionality becomes clearer once we look at the 29th-Street-Mall-to-CU segment alone, in Figure 21. Total HOP ridership at all times of the day is closely linked to this part of the route. The clockwise direction, shows the heaviest ridership in the morning headed towards the CU campus from student housing and car parking to the north. Ridership in the afternoon is away from the campus, as shown by the purple line, back towards student housing and car parking.

In Figure 22, ridership throughout the day on the Pearl Street segment is isolated. Ridership towards downtown is slightly higher in the morning. Total ridership on this segment is fairly flat throughout the day.

In Figure 23, ridership on the University Hill segment is shown isolated. On this segment, ridership towards CU campus (counterclockwise) is slightly higher in the morning, and to a lesser degree in the afternoon. As on the Pearl Street segment, ridership is fairly low and flat all day.

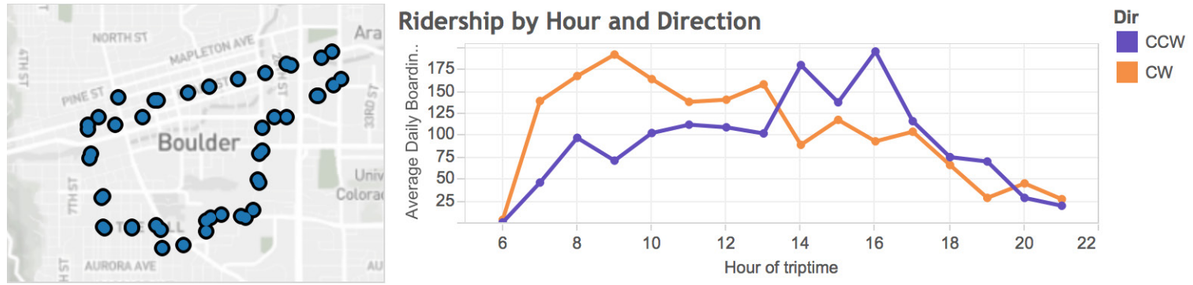



Figure 20: Boardings at all HOP stops, in each direction, each hour of the weekday. Data source for all charts on this page: Boardings counts on a Monday and Tuesday in April. For more detail, see Appendix B.

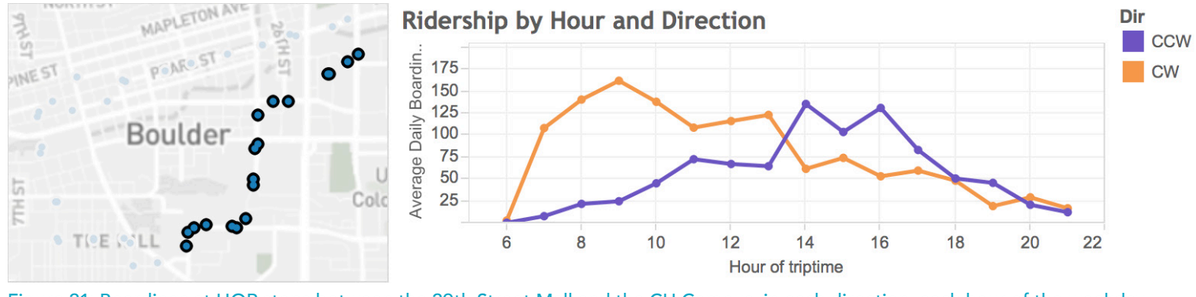



Figure 21: Boardings at HOP stops between the 29th Street Mall and the CU Campus, in each direction, each hour of the weekday.

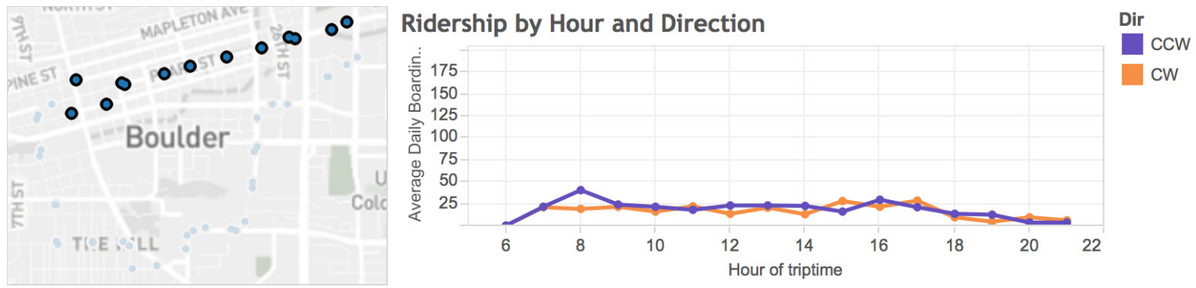



Figure 22: Boardings at HOP stops on Pearl Street and downtown, in each direction, each hour of the weekday.

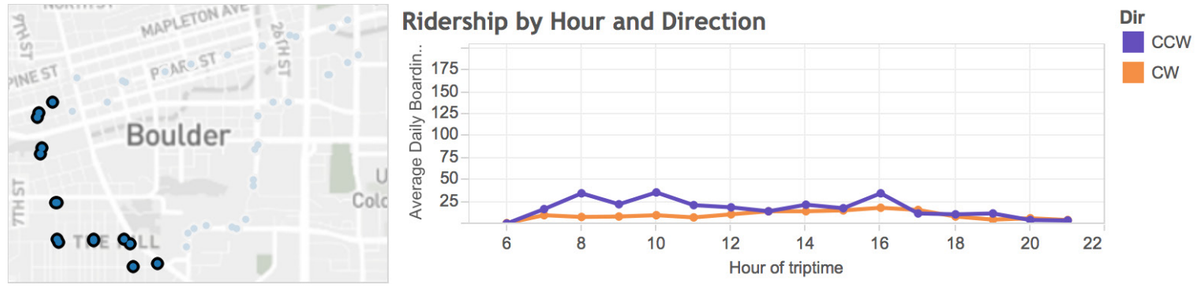



Figure 23: Boardings at HOP stops in University Hill and downtown, in each direction, each hour of the weekday.

### Average Occupancy

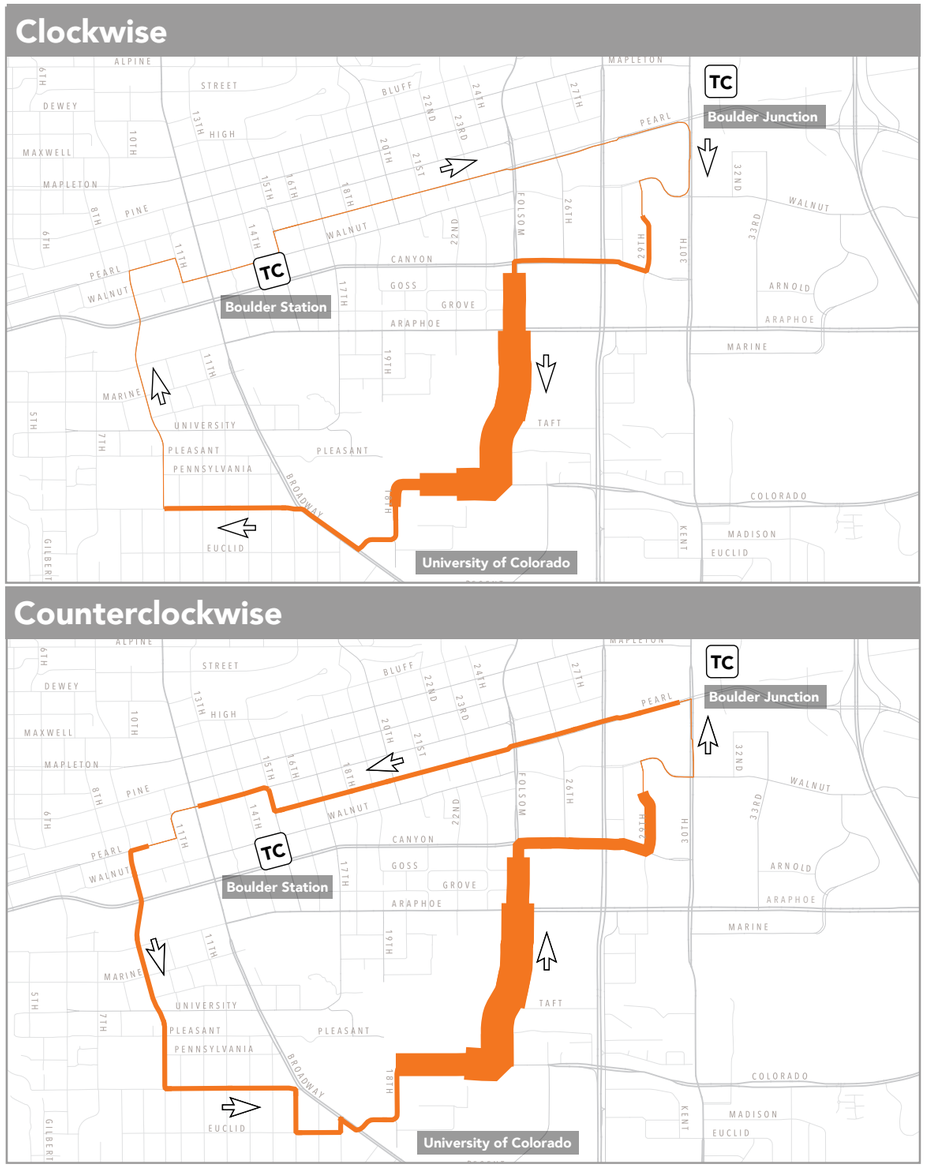
The boardings and alightings data collected in April 2016 (as described in Appendix B), can be used to estimate the number of passengers on the HOP between every pair of stops along the route. This is called a "load-line" and it is presented graphically in the maps at right.

The large difference in boardings at HOP stops on different segments of the loop suggest that the HOP is functioning as two or three mostly-independent segments. To confirm that, however, we would need to assess how many of the HOP's riders are traveling from one segment to another – riding "around the corners."

The "loadline," at right, can help us visualize the answer to that question. There are two places where the bus has just 6-8 people on it, on average, in either direction: at 11th Street, downtown; and at 30th and Walnut. (Note that the loadline shows *average* weekday loads; at different times of day the buses will be much more full, and much more empty, than the average.)

One cannot know, without collecting data that links individual boarding locations to individual alighting locations, exactly what percentage of trips go through these low-load "corners" of the route. However, based on the load pattern, it is likely that only a small minority of riders' trips go through these points. The majority of HOP riders on any given day may experience the HOP not as a loop but as a line (even if the line zigzags as it forges a diagonal path through the street grid).

In light of this theory, the following sections examine three segments of the HOP that each provide reasonably direct travel, separately.




## HOP Average Occupancy

Weekday average number of passengers on board between each pair of bus stops.

- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 17

Data source: April 2016 count of boardings and alightings on all transit vehicle trips on a Monday and Tuesday. For more information, see Appendix B.

Figure 24: Average weekday load by segment. Buses are most full around CU and student housing areas. Buses are least full at 30th & Walnut and at 11th Street downtown.

## Segment 1: Campus and Mall

The University segment receives the majority of the HOP boardings, about 65% of the total. This equates to about 2,200 passengers per day. The vast majority of these riders seem to be students riding between their residences and the campus.

Ridership on this segment is probably very sensitive to frequency. The average frequency offered by the HOP during school days and hours is 9 minutes; the average wait will be one-half that frequency, 4.5 minutes. If students had to wait longer than 4.5 minutes, on average, for a bus, walking to campus would be faster.

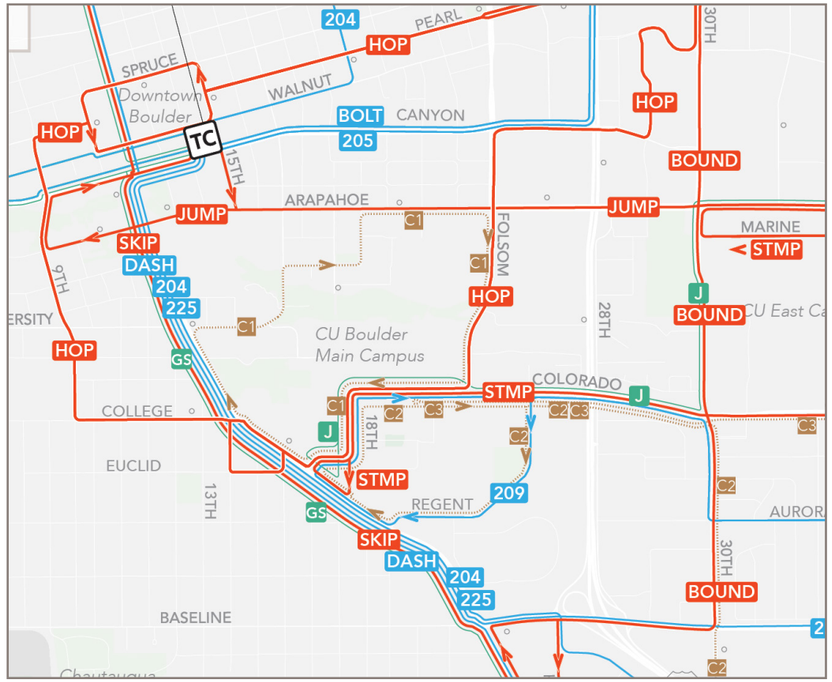
(This is why short-distance routes, like streetcars or downtown circulators, must be *extremely* frequent to attract ridership. The shorter your transit ride, the more likely you are to just start walking, and get to your destination sooner.)

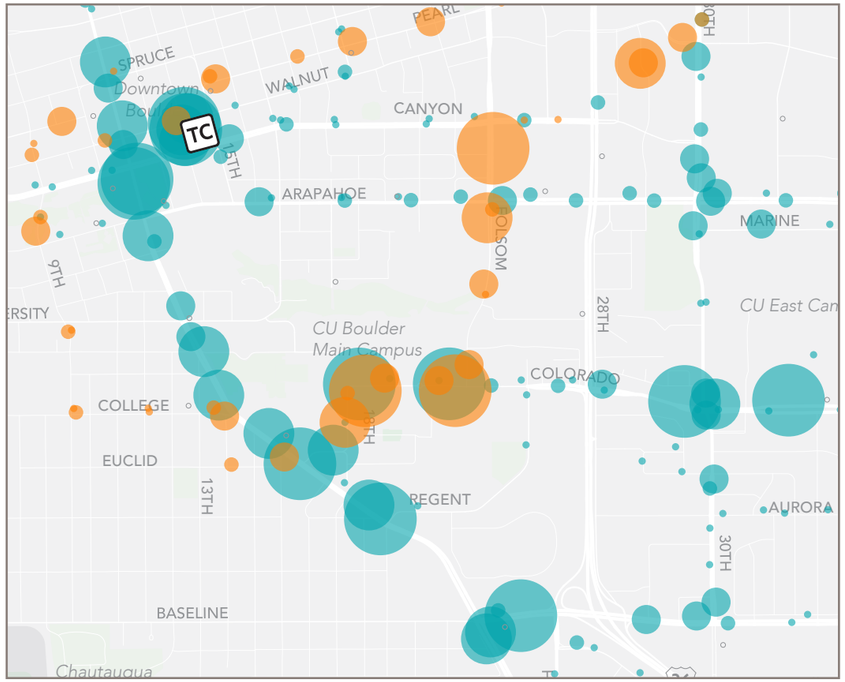
The high boardings at the 29th Street Mall (seen as two overlapping orange dots, in the map at far right) may relate partly to the Mall being a major destination for shopping, errands and jobs. However, more of those boardings are likely attributable to the large, free parking garage at the Mall. If a person drives to central Boulder and wishes to avoid paying for parking or moving their car midday, the 29th Street Mall is one of the few places they will find to park for free all-day.

Of the people who reported driving to the HOP, most of them boarded at 29th Street Mall. About 3/4 of them headed from the Mall to CU, and the other approximate 1/4 headed to downtown. However, the number of people who answered this sub-question is small, and their responses cannot be applied with confidence to the entire population of HOP riders. (More detail about the sample size and margin of error for this survey is provided in Appendix B.)

There is surprisingly little ridership between CU and the Boulder Junction Transit Station, and few transfers from other routes on 30th, suggesting that the HOP is not carrying many people the "first/last mile" from where they arrive on an intercity transit route.

Finally, it is worth noting what an enormous quantity of frequent service converges on the CU campus (as shown in map at near right). Universities are almost always sources of high transit ridership, so this quantity of service is unsurprising. However, it seems likely that if RTD, the City and CU were to work from a single, integrated network plan in this area, even higher ridership could be achieved from the partners' combined investment.



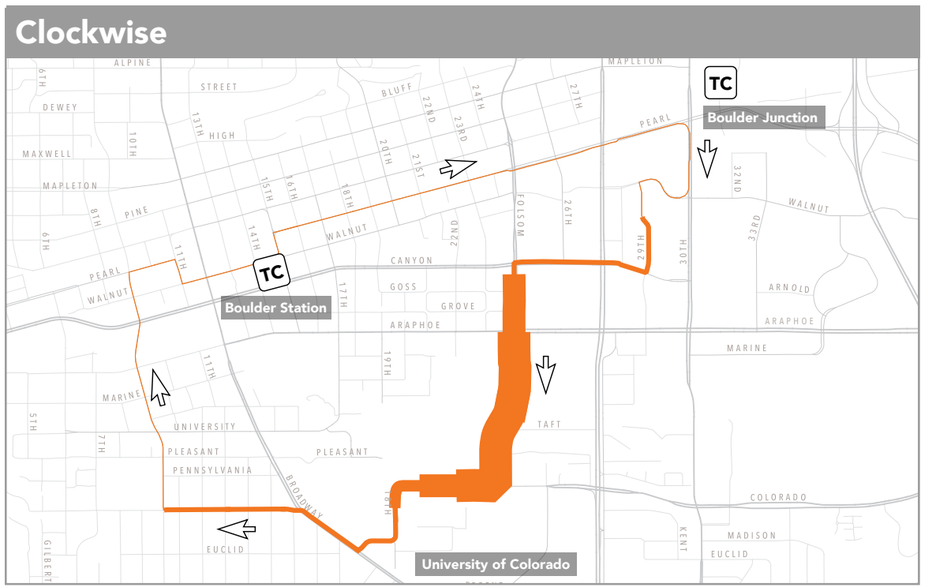




Figure 25: The map at top left shows the transit network around CU campus. The map at top right shows boardings at all local RTD and HOP stops for the same area. (Boardings on CU shuttles and RTD intercity routes are not shown here.) At bottom, a diagram shows the pattern of bus-fullness around the HOP loop.

## Segment 2: University Hill

Ridership on the University Hill segment of the HOP is low, both in terms of the number of boardings at stops in this segment and the average passenger load on the bus riding through.

Why is ridership relatively low on this segment?

The biggest factor is likely to be the number of people and destinations close to the HOP route. This is the least-dense part of the city served by the HOP. "Density" is a word with many cultural connotations, but in fact it has a simple mathematical definition: the amount of stuff in a given space. The fact that this neighborhood is low density means that there are simply fewer residents, jobs, activities or destinations within walking distance of any HOP stop on 9th Avenue than there are for most other HOP stops.

The other factor is the degree of "competition" with transit services on Broadway:

- With so many routes, especially frequent routes, going long distances on Broadway, there's little reason for anyone to walk to a HOP stop if they are closer to Broadway.
- Even when people are closer to a HOP stop, if they are making a trip that is more than 1/2 mile long to the north or south, the HOP won't get them there.
- Finally, even if they are making a very short trip (e.g. to downtown or to CU), the average waits for service on Broadway are even shorter than the waits for the HOP (2.5 vs. 4.5 minutes, on average), so it will sometimes be worth walking a little farther to a stop on Broadway.

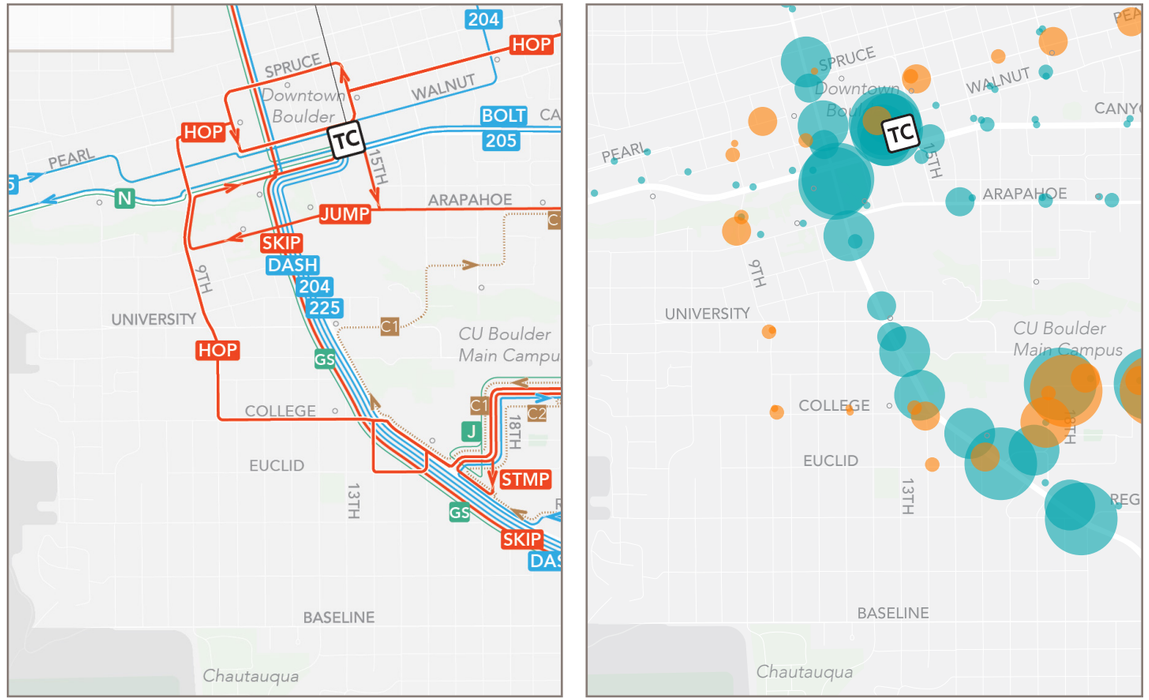
Regardless of which services are winning any "competition" along this corridor, the transit ridership potential here is being divided between the HOP and Broadway routes, and will therefore be lower on both sets of services than it could otherwise be, if the routes were consolidated onto Broadway or spaced farther apart. (In a frequent grid, the ideal spacing between parallel frequent routes ranges from 1/2 to 1 mile, depending on how far people are willing and able to walk to a frequent service. 9th Street and Broadway are about 1/5 of a mile apart.)

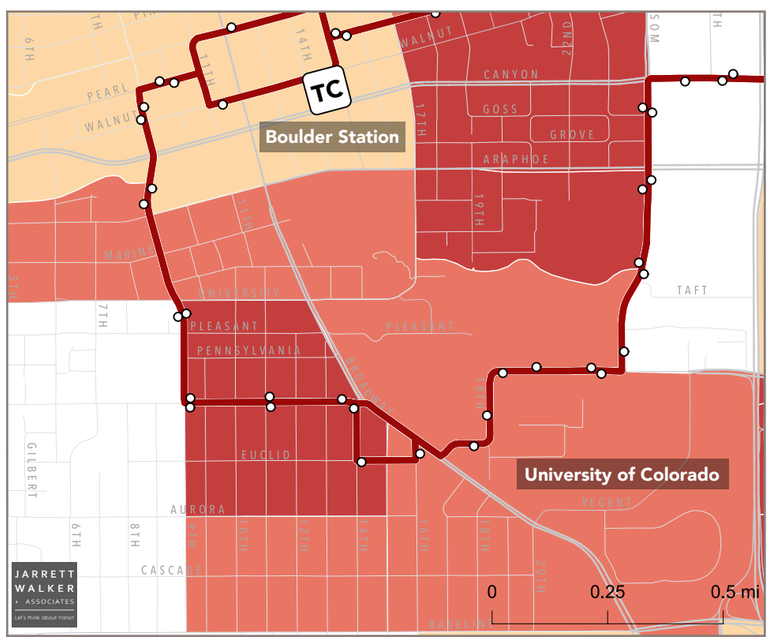
Ridership is not transit's only purpose, which raises the question: Is there an important, non-ridership reason to run service here? Does the HOP on 9th Street serve a valued coverage goal? If so, is such high frequency required to serve that goal?

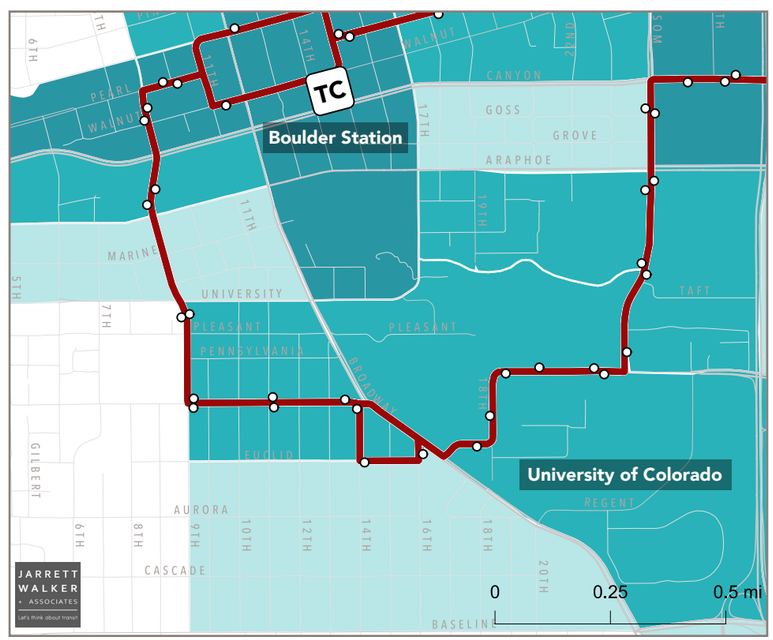
Figure 26: The maps at right show the Boulder Transit Network, and boardings at each stop, in the University Hill neighborhood.

The pair of maps at bottom show the density of residents (in red, at left) and jobs (in blue, at right) for the same area. In all of the maps of Boulder density – showing the density of young and old residents, and of zero-car households – the University Hill neighborhood stands out as one of the lowest-density places within the central city. This means that at any given transit stop, the number of people or destinations within walking distance will simply be lower than in other, denser places. This partly explains why HOP boardings are low in the University Hill neighborhood.

A complete set of maps showing this demographic information is shown in the Appendix starting on page 35.



## Segment 3: Pearl Street

The Pearl Street segment of the HOP's route has, at first glance, surprisingly low ridership. It is fairly dense with jobs and residents, has a mix of uses, there are major trip generators at both ends of the corridor, it is straight, and it completes a frequent transit grid.

Why, then, is transit ridership low along the length of Pearl Street?

- The Pearl Street segment is the "flat-top" of the loop. This means that a trip from Pearl Street to most other places on the loop will require out-of-direction travel. Only trips from Pearl Street to University Hill will feel reasonably direct yet, as discussed in the previous section, University Hill has the lowest density of all the places served by the HOP. This means that there will naturally be fewer people going to and from the Hill than the other places on the HOP's route.
- The Boulder frequent transit grid is missing a north-south route on or near Folsom Street. The lack of such a route means that the Pearl Street segment of the HOP can't be used to access CU (at least, not without a long ride around the loop). For someone starting downtown, the faster way to get to different parts of campus or campus-adjacent housing will be via frequent service on Broadway or Arapahoe rather than via the HOP.
- To a certain degree, frequent service on Arapahoe and the multiple infrequent routes on Canyon may be "competing" with the HOP. These three east-west corridors are so close to one another that they are splitting east-west ridership potential among them.
- Because the HOP is only useful for very short trips, anyone traveling beyond Pearl or 30th will naturally walk to service that takes them farther, on Canyon or Arapahoe.
- The HOP turns off of Pearl Street before it reaches some major destinations that are east of 30th. In a sense, the HOP treats 30th as the edge of the city, rather than a junction and a center.

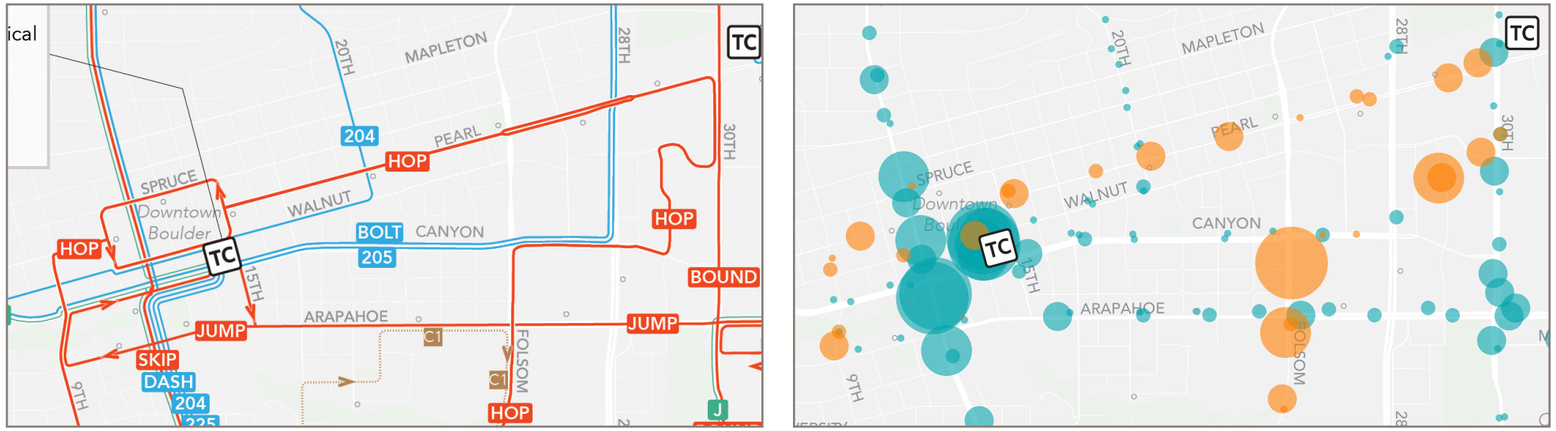



Figure 28: The maps above show the Boulder Transit Network, and boardings at each stop, along Pearl Street to the Boulder Junction Transit Station.

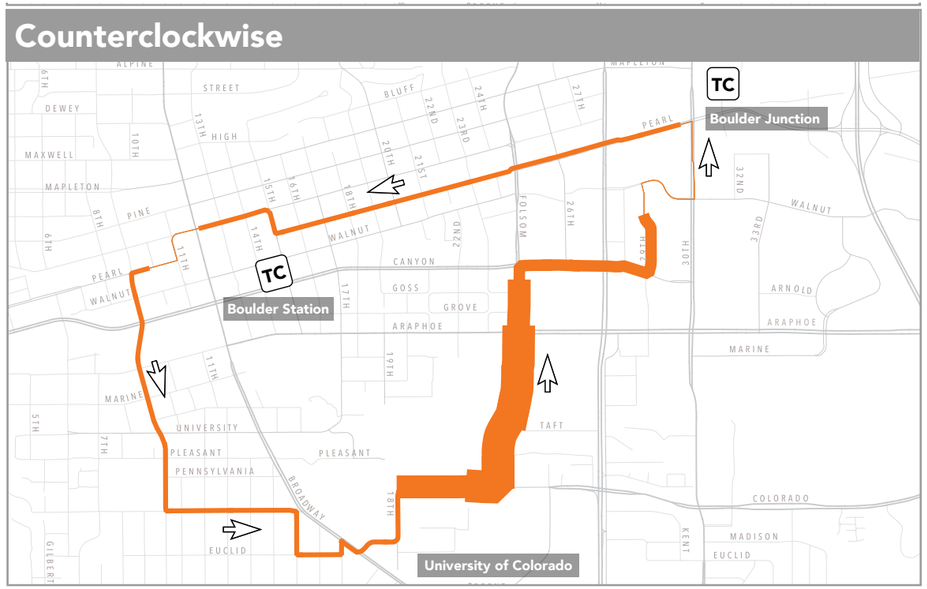



Figure 27: In this diagram, the average fullness of HOP buses (in the counter-clockwise direction) is represented by the thickness of the orange line. Ridership is low on Pearl Street, but it is lowest on the segments that connect Pearl Street to CU and Pearl Street to University Hill.

- Partly because the HOP turns south, the walk between Boulder Junction (where the Flatiron Flyers and FLEX stop) and the nearest HOP stop (shown in Figure 29 at right) is more than 1/4 mile long. While 1/4 mile is a very standard walking distance for the start or end of a trip, it's unusual to have such a long walk as part of a *transfer*. This may explain why so few people transfer to the HOP and use it for the first or last mile of a regional commute.

- More generally, the Flatiron Flyers don't only serve their endpoints, at the Downtown and Boulder Junction Stations. They also make limited stops as they enter the city. The FF routes by themselves get people within walking distance of most major Boulder destinations (such as CU campuses and downtown), or to a convenient transfer to another frequent route before crossing the HOP. The HOP does not add much to what the FFs and other frequent routes already provide within the city.

While the development patterns east of 30th are less charming and walkable than west Pearl, job and activity density is actually quite high there (especially after recent developments), and one could expect the area to generate high transit ridership, in response to useful transit service. This ridership would arise not just from employees (whose density is visualized in the map on page 36) but also from shoppers, visitors, people accessing services, and people transferring to other transit routes.

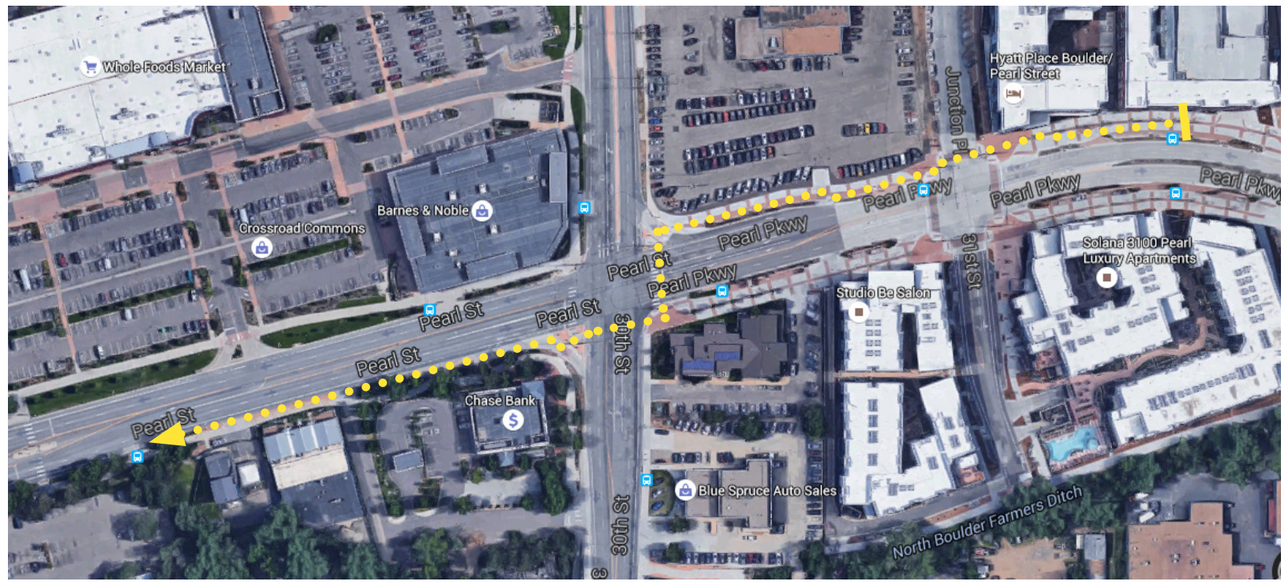



Figure 29: Transferring from routes that stop at Boulder Junction to the nearest HOP stop involves an 8-minute walk, which may partly explain why few people do it.

## Transfers

Downtown circulators are often expected to provide a "first/last mile" connection for longer-distance commutes. The HOP might be expected to serve this purpose for people riding intercity routes (such as the Flatiron Flyers or FLEX) into the Downtown or Boulder Transit Stations.

The HOP can also be expected to function as part of Boulder's frequent transit network (shown in red on the map on page 13). People can go from anywhere to anywhere, on the frequent network, with a single short transfer. If the HOP were an integral part of this network we would expect to see many transfers to and from other frequent routes.

A transfer survey, implemented on HOP vehicles in April 2016, shed some light on both of these questions. (More detail about this survey is provided in Appendix B, starting on page 40.)

The majority of surveyed riders reported that they walked to the HOP, as shown in the chart at top right.

The next most common response was, surprisingly, from people who drove to the HOP. Of the people who reported driving to the HOP, most of them rode from the 29th Street Mall to CU; a smaller proportion rode from the Mall to downtown (as shown in the chart at middle, right). Because both CU and downtown have parking restrictions, whereas the Mall does not, it seems likely that they are using the HOP to avoid parking hassle and cost.

Only about 9%, or 35 survey respondents, transferred to the HOP from another transit route. In order to assess whether the HOP is functioning as a part of Boulder's frequent transit network, the City could compare its transfer-boardings rate (9%) to rates on other frequent routes in Boulder.

This data sample is too small to draw any conclusions about exactly *which* routes people use in combination with the HOP. However, only about one in five survey respondents who transferred said that they came from an intercity route (like the Flatiron Flyers or FLEX). The rest came from local routes. This suggests that the HOP is not functioning as a "first/last mile" solution for large numbers of regional commuters.

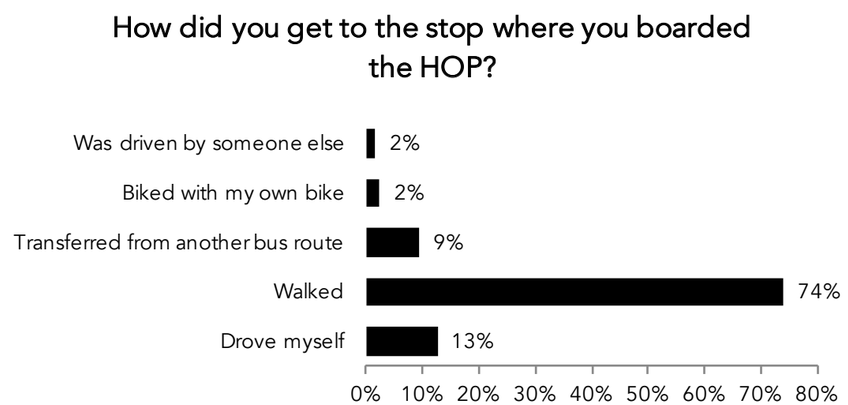



Figure 30: Of 380 surveyed passengers, only 9% transferred from another route; 13% drove and parked. Data source for both figures on this page: April 2016 survey of all boarding passengers on a Wednesday morning. For more information about this data, see Appendix B.

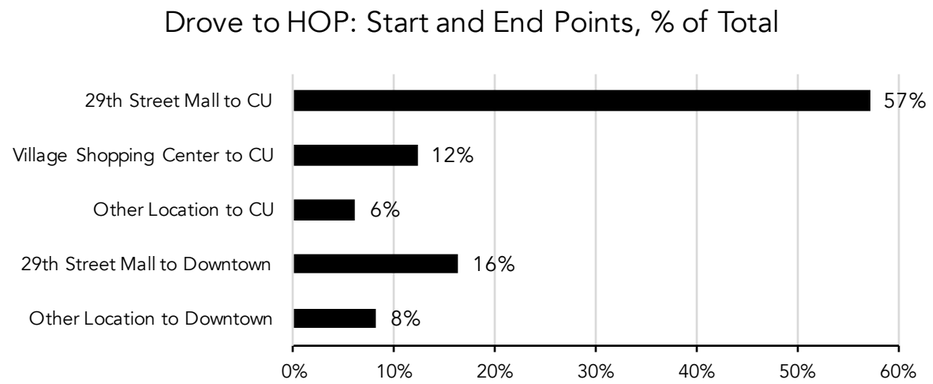



Figure 31: This chart shows the start and end points of surveyed trips that involved driving to the HOP. However, only 49 people responded to this question. Thus these results cannot be taken as representative of the entire population of HOP riders with confidence. For more information, see Appendix B.

## Fare Analysis

Fare data for the HOP reveals just how important CU is to the route's ridership. The charts on this page show fare data for all weekdays in 2015.

The chart in Figure 32 shows that the CU Pass, available to and paid for by CU students, is the dominant form of payment. About 30,000 CU students have a transit pass.

Passes issued under Boulder's ECO Pass program are a distant second. About 8,000 CU staff and faculty have ECO Passes. The ratio of CU student-to-staff transit passes (30,000 to 8,000) is similar to the ratio of CU Passes to ECO Passes among HOP fares, shown in Figure 32, which suggests that many of the ECO Passes used on the HOP likely represent CU employees.

This chart underscores the great importance of student ridership to the overall ridership of the route – if it weren't already clear from ridership patterns, CU students make up the lion's share of HOP ridership.

However, CU ridership is seasonal. The chart in Figure 33, at right, reveals how much ridership (here, measured using the number of fares collected) drops when CU is not in session.

**CU student passes make up a majority of all fares on the HOP.**

It is likely that CU staff and faculty, and some students, ride year-round. Regardless, without the enormous number of students commuting to and from campus, ridership in the summer is less than half of what it is at its spring and fall peaks.

Summer months are also the time of the year where active modes, such as walking and cycling, are most attractive, since the weather presents less of a barrier. While cycling and walking can be complementary modes for transit because they extend trips, when the weather is nice, they are more likely to be competing with a short-distance route like the HOP. The frequency of HOP service is lower when CU is not in session, which may further depress ridership among non-students.

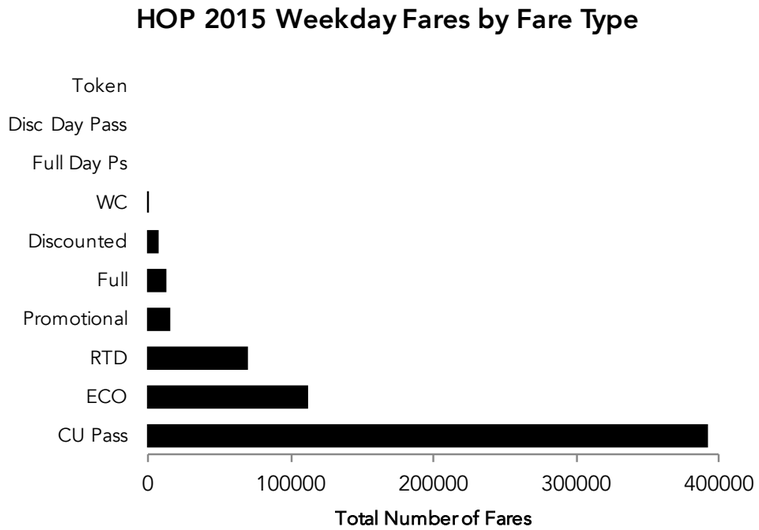



Figure 32: The CU Pass, paid for by and issued to all CU students, dominates the fares paid on the HOP. The ECO Pass is a distant second; an unknown number of ECO Pass HOP riders are CU staff and faculty. Data source: VIA 2015 farebox records.

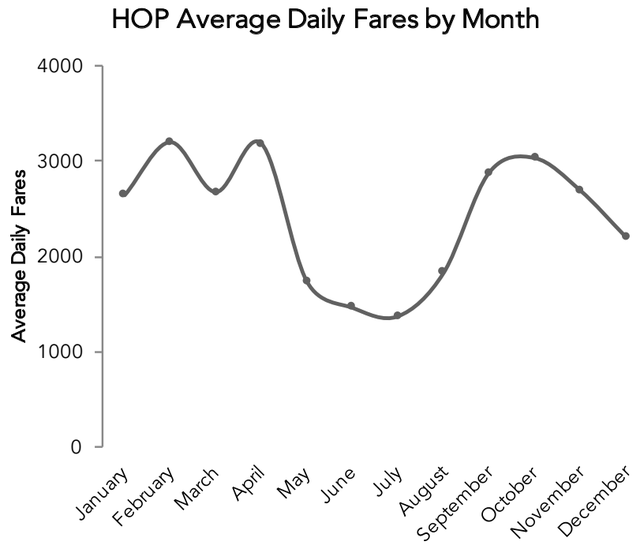



Figure 33: Total fare collection tracks with total ridership on the HOP, and tracks very closely with CU's academic calendar. However, HOP frequencies drop in the summer, which may also contribute to a reduction in use by non-CU-student riders. Data source: VIA 2015 farebox records.

## HOP Observed Headway Intervals

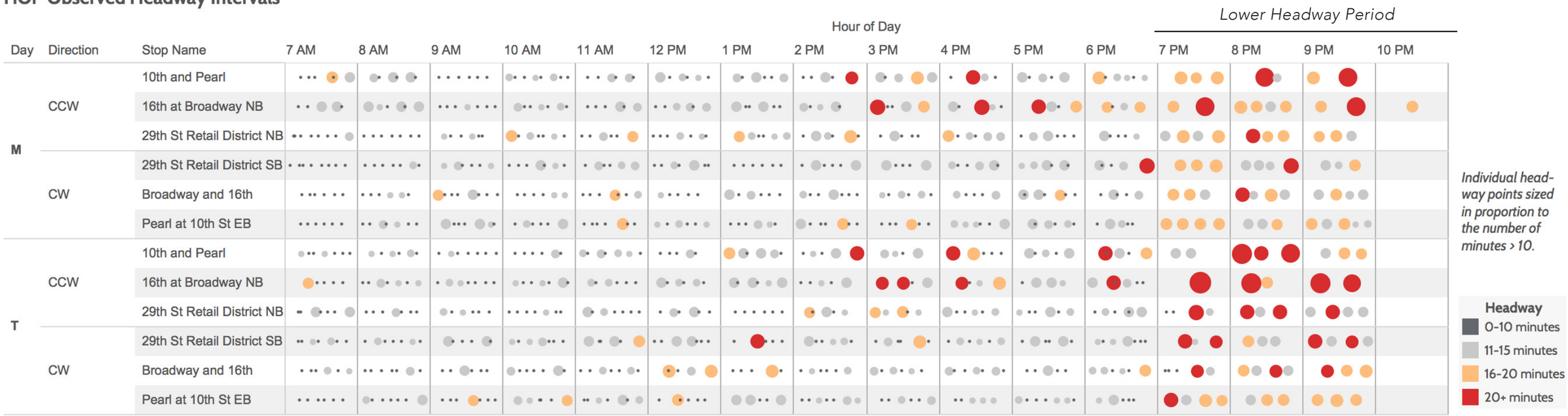



Figure 35: This diagram shows the time between arriving buses (the maximum wait time) throughout the two weekdays on which data was collected. Waits that were longer, and much longer, than promised are shown in orange and red dots, respectively. During daytimes on weekdays, when the frequency is advertised as "7-10 minutes," orange and red dots represent major reliability failures. They tend to appear during the PM rush hour, and in the counter-clockwise direction.

## Reliability

Most transit services measure reliability in terms of the proportion of trips that arrive within some window around the scheduled time.

The HOP is actively managed to maintain a consistent "headway" between vehicles, and thus has no scheduled arrival and departure times. When transit services are very frequent, what becomes most important to customers is the consistency of short waits. The measure of reliability for the HOP is thus not whether it is "on time" according to some schedule, but, How reliably do daytime waits exceed the advertised 7-10 minutes?

In the graphic above, reliability data is shown for an entire weekday, for three locations. (This data was collected in April 2016. For more information, see Appendix B.) Each observed interval between arriving buses is shown as a dot, sized and colored based on the number of minutes. Headway intervals that were as-advertised, i.e. 10 minutes or less, are small black dots.

The chart in Figure 34 shows the same data in a different way. Each bar shows what percentage of headways were within each interval.

Headways over 10 minutes are fairly common throughout the day. Headways over 15 minutes are rare, until after 7:00 pm, when the frequency is intentionally reduced.

During the day, when headways are supposed to be 7–10 minutes, severe failures (orange or red dots) are most common during the afternoon and PM rush hour, when transit is most vulnerable to delays as a result of the combination of congestion and high ridership.

Severe headway failures are more common in the counterclockwise direction (this is visible as the wider red and orange bands in the "CCW" bar in the chart at right). This may be caused by the greater number of left turns made in a counter-clockwise loop, which lengthen the amount of time a bus needs to negotiate an intersection.

The average weekday headway calculated from this data is 9.3 minutes. However, averages do not tell us very much about the wait that passengers experience *reliably*. An average will reflect the quantity of service being supplied on a route, but not passengers' level of confidence in wait

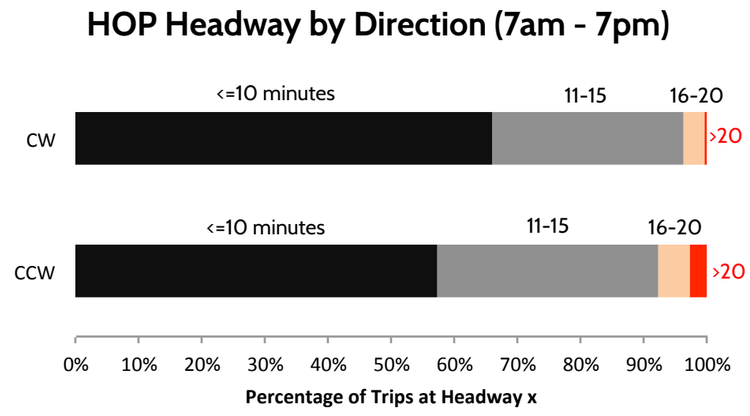



Figure 34: This chart shows how often the HOP delivers short waits. Data source for both figures on this page: April 2016 survey arrival times on a Monday and Tuesday.

times and total trip times.

A better way to think about and measure reliability is to describe a passenger's odds of waiting longer than a certain amount of time. The data above suggests that the HOP delivers maximum waits of 10 minutes 62% of the time (averaging both directions of travel, for the two weekdays analyzed).

This means that almost 2 out of 5 times that the average weekday HOP user rides the HOP, the time between buses is longer than the advertised maximum. This is a low level of reliability, and is likely depressing ridership below what it otherwise could be.

The slower buses travel, the more of them are needed in order to deliver the same frequency to waiting passengers. As the HOP has slowed down over the years, providing its original frequency has become more difficult. Doing so now would require the addition of both buses and drivers (i.e. both one-time and ongoing investments), or changing the route so that it becomes either faster or shorter (or, more likely, both).

# 4 Fleet Condition

## HOP Vehicles

As described in the previous chapter, the HOP is no longer reliably offering the frequency of service it once did. This is probably due to a decline in the speed of the HOP buses since the route was created in 1994.

Getting back to a higher-frequency service would require either shortening the route, speeding up the buses, or paying for more buses and drivers.

The current HOP fleet is aging, and could not reliably support the HOP's advertised 7-10 minute headway even with the addition of operating budget to pay for more drivers.

The fleet consists of ten Gillig transit coaches owned by VIA, all of them low-floor models 30 feet in length. In addition, VIA has recently leased two 35-foot Arboc buses, because reliably maintaining the HOP's frequency requires having spare vehicles in case of breakdowns. The table at right in Figure 36 lists these buses and their ages.

When purchased, the Gilligs were rated as 12-year life vehicles. The FTA has since downgraded them to 10-year vehicles. They are operated in urban conditions, rarely exceeding 30 miles per hour, and have frequent stops. These conditions increase wear and tear on buses, resulting in the shorter 10-year life rating. Both the 2004 and 2006 vehicles have exceeded or reached the ends of their useful lives.

On average, HOP vehicles accrue about 30,000 miles annually.

The 2004 vehicles have exceeded their standard 10-year life span, but will need to remain in service for another 18 months, until late 2017 or early 2018. State FASTER funds were recently secured by VIA (in partnership with the City and RTD) to replace these with similar clean diesel vehicles, but manufacturers' delivery times on new vehicles is 16 to 18 months. The 2004 vehicles are likely to be 14 years old when they are replaced.

The FASTER grant also includes funds to replace the engines and transmissions in two of the 2006 vehicles. This will occur in 2016 and will extend the life of those buses by 2-3 years. It should be noted that this is not a full rehabilitation, but only a stop-gap measure to keep the vehicles running until they can be replaced. Replacing the 2006 buses in 2019 would result in these vehicles having 13 years of service before they are retired.

While limited federal grant funding is available for vehicle purchases, it requires a local match contribution. The match ratios vary by grant. The FASTER grant referenced above was a 75%-25% (state-local) match; RTD contributed $200,000 and the City of Boulder contributed about $150,000.

VIA has also applied for a grant from the federal Low and No Emission Vehicle Deployment Program ("LoNo"), enough to fund five 35-foot electric buses and charging stations. One charging station would be located at the VIA facility and two quick-charge stations would be placed along the route.

For the LoNo grant, VIA, the City and RTD have partnered with Proterra for the vehicles and infrastructure. The match ratio required for these funds is 80%-20% (federal-local), with RTD committing $600,000 in match, the City of Boulder committing $80,000, and VIA contributing $50,000.

VIA has also submitted a similar application for federal funds from the federal Bus and Bus Grants program (FTA 5339), and hopes that at least one bus purchase is funded, or that between the two outstanding grant applications adequate funds are received to fund the current vehicle replacement needs.

At this point, the City should expect that the older HOP vehicles will have mechanical problems and offer lower passenger comfort as they age, until they can be replaced. In addition, maintenance problems impact reliability, as buses with a problem must be taken out of service and replaced with a spare. This interruption in service can result in a one-time or cascading delay to passengers along the route.

VIA's and the City's ability to obtain adequate funds to establish a routine replacement program has been an ongoing challenge. The State of Colorado and the Denver-Boulder-Aurora Metropolitan area, in particular, are short on funds for capital projects such as bus replacements.

| Year | Make-Model | Passenger Capacity | | Estimated Mileage | Desired Replacement |
|---|---|---|---|---|---|
| | | Ambulatory | Wheelchair Positions | | |
| 2004 | GILLIG-823D | 30 | 2 | ~400,000* | 2018 |
| 2004 | GILLIG-823D | 30 | 2 | ~400,000* | 2018 |
| 2004 | GILLIG-823D | 30 | 2 | ~400,000* | 2018 |
| 2006 | GILLIG-823D | 30 | 2 | 314,619 | Rehab-2016; 2018-19 |
| 2006 | GILLIG-823D | 30 | 2 | 375,020 | Rehab-2016; 2018-19 |
| 2006 | GILLIG-823D | 30 | 2 | 294,090 | 2017-18 |
| 2009 | GILLIG-823D | 30 | 2 | 227,674 | 2020 |
| 2009 | GILLIG-823D | 30 | 2 | 199,724 | 2020 |
| 2009 | GILLIG-823D | 30 | 2 | 197,796 | 2020 |
| 2009 | GILLIG-823D | 30 | 2 | 183,326 | 2020 |
| 2015 | ARBOC | 35 | 2 | ~3,000 | N/A; 3-year lease |
| 2015 | ARBOC | 35 | 2 | ~3,000 | N/A; 3-year lease |
| * Some buses have had their hubometers changed; 400,000 is an estimate of their total mileage. | | | | | |

Figure 36: Half of the HOP's fleet is made of vehicles expected to last 10 years that are now 10-12 years old. Data source: VIA.

# A Appendix: Development and Demographic Context

## Development Patterns

Many people are under the impression that transit ridership is entirely within the control of a transit operator, but this is rarely the case. Land use, development, zoning, urban design, density, highways, and street patterns are significant drivers of transit ridership.

For this reason, transit providers collaborate with municipal planners, counties, and other agencies to write plans and policies recognizing the relationships among these factors. These factors are outside the direct control of the transit provider, and yet they impact ridership and the costs that must be born to attract that ridership.

A good way to visualize the different ways development and land use impact ridership and costs is to ask: *"How far do we have to drive a bus to serve 100 people or jobs?"* The longer this distance is, the higher the cost to reach those people and jobs.

If a transit provider is pursuing high ridership, it will naturally focus service on places where it has to drive a bus only a short distance to serve large numbers of people. If high ridership is not the goal, then the agency is free to drive longer distances, at a higher cost, to reach smaller numbers of people.

Figure 37 offers a simple distillation of four ways that the built environment affects transit ridership potential:

- **Density**: How many people, jobs, and activities are near each bus stop?
- **Walkability**: How many of the people near the bus stop can actually walk to the bus stop?
- **Linearity**: Can transit reach large numbers of people by traveling straight, direct paths?
- **Proximity or Continuity**: Can transit reach large numbers of people without crossing long, low-demand gaps?

A transit provider can influence the level of ridership their services generate, within their fixed budget, by targeting corridors and places where the "Ridership Recipe" is in effect. However, they cannot directly control the urban form of the places they serve. Without dense, walkable places with connected streets, where demand is continuous along straight transit paths, even the best transit service is unlikely to achieve high ridership. The transit agency can try to provide useful service, but without support from the built environment, the potential for transit ridership will always be low.

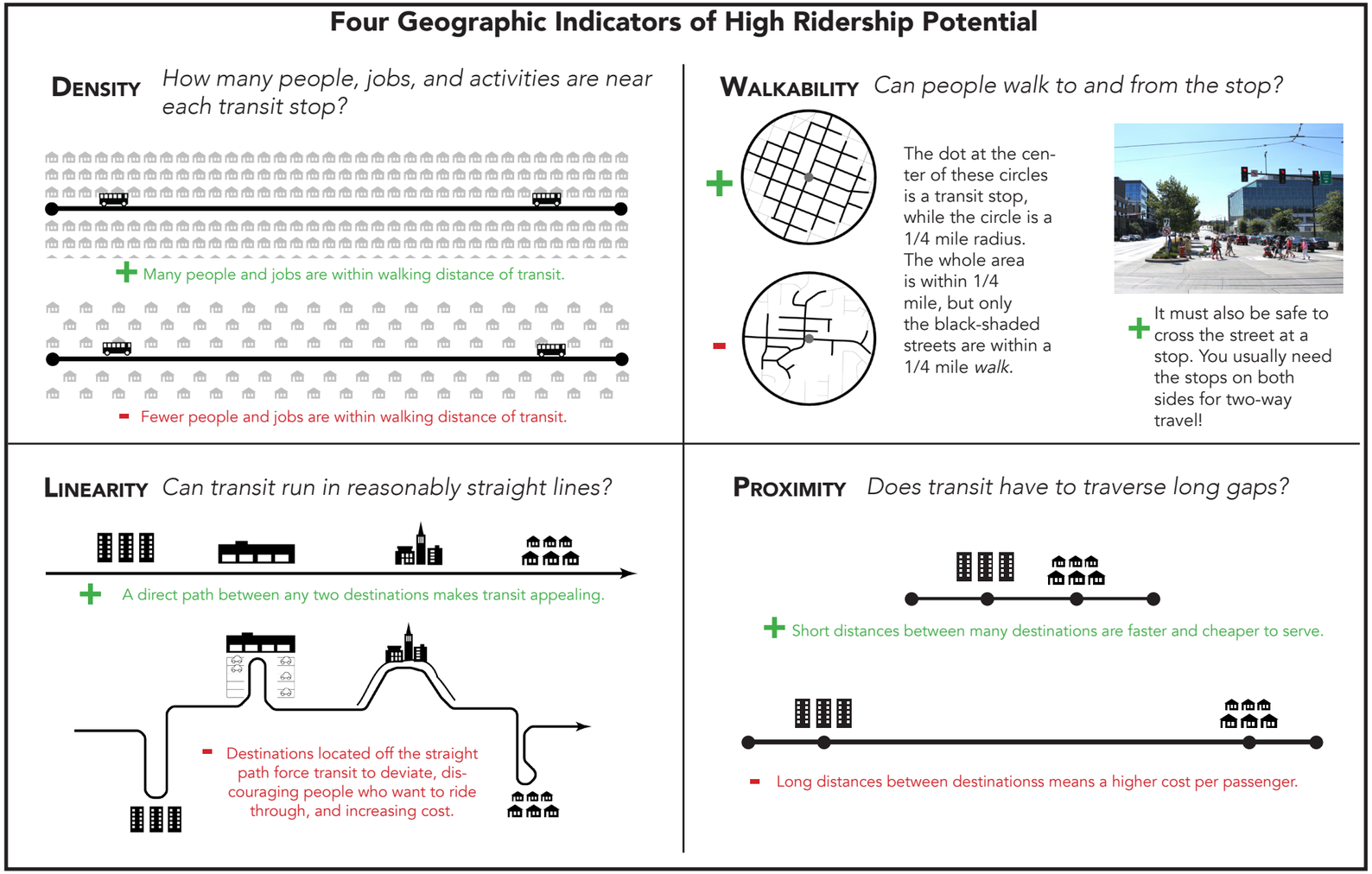



Figure 37: Certain aspects of transit service, land uses and the built environment are key to attracting high ridership relative to cost.

In planning, people sometimes react strongly to the word "density" based on their personal experiences and cultural assumptions. Yet density describes a spatial fact that matters enormously for transit – it is simply the number of people close to any given transit stop.

Central Boulder offers most of these characteristics in spades: it is continuously dense with people and activities, very walkable, with few empty gaps inside the city. It also offers many straight streets on which transit can follow linear paths that will feel direct to passengers.

By design the HOP does not offer linearity. Only for short trips will traveling on the HOP feel like a reasonably straight line (reasonably, relative to the paths that one can take using other modes). Because people only like to travel in circles (or even semi-circles) when they are at leisure, and because most of the people traveling around Boulder on any given day are *not* at leisure, the HOP's ridership is almost entirely along its linear segments.

## Residential Density

The first indicator of transit ridership potential is density: the amount of stuff that matters to people within the fixed area around a bus stop.

Figure 38 shows the residential density by census block groups for the area served by the HOP. The areas of highest density can be seen in dark red, south of Pearl and west of Broadway.

From this map, we can observe a general pattern of high residential density throughout most of the central area of Boulder and neighborhoods adjoining CU. On this map, the Boulder Junction area appears to have quite a low level of residential density, but the data upon which this map is based[1] may not accurately represent more recent residential development in that part of the city.

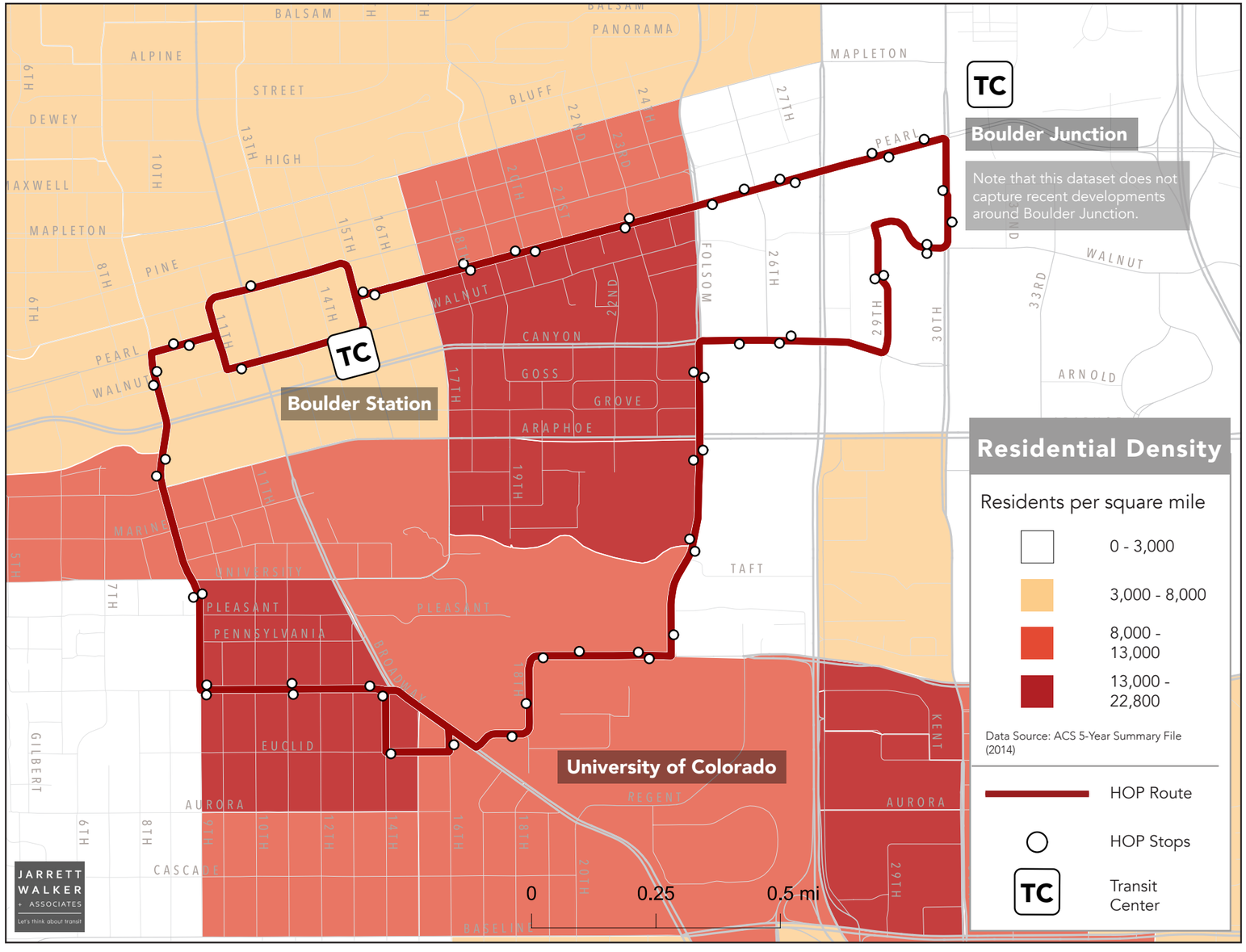



Figure 38: This map shows the density of residents in neighborhoods around the HOP route. Note that recent residential developments in and around Boulder Junction are not captured by this Census dataset.

1 ACS 5 year summaries are extrapolated from the most recent decennial Census (2010 in this case).

## Job Density

Figure 39 shows the density of jobs in census block groups in Boulder.

Employment density is an important measure of transit ridership potential, because it indicates places where people are working (and thus commuting to) as well as destinations for various business, social and service activities.

The current HOP route mainly serves areas with a high density of employment, particularly in Downtown Boulder and the commercial and office area east of Folsom. East of Folsom there are multiple shopping centers and large retail businesses, as well as corporate offices such as Google Boulder.

While the main CU campus appears to have a lower employment density than some of these other block groups, we must keep in mind that an enormous number of "commuters" go there every day, though they are not counted as employees. They are CU students.

If we compare this map and the map of residential density, on the previous page, one area on the HOP route stands out for its very low overall density of residents and commercial activities: the University Hill neighborhood, west of 9th Avenue.

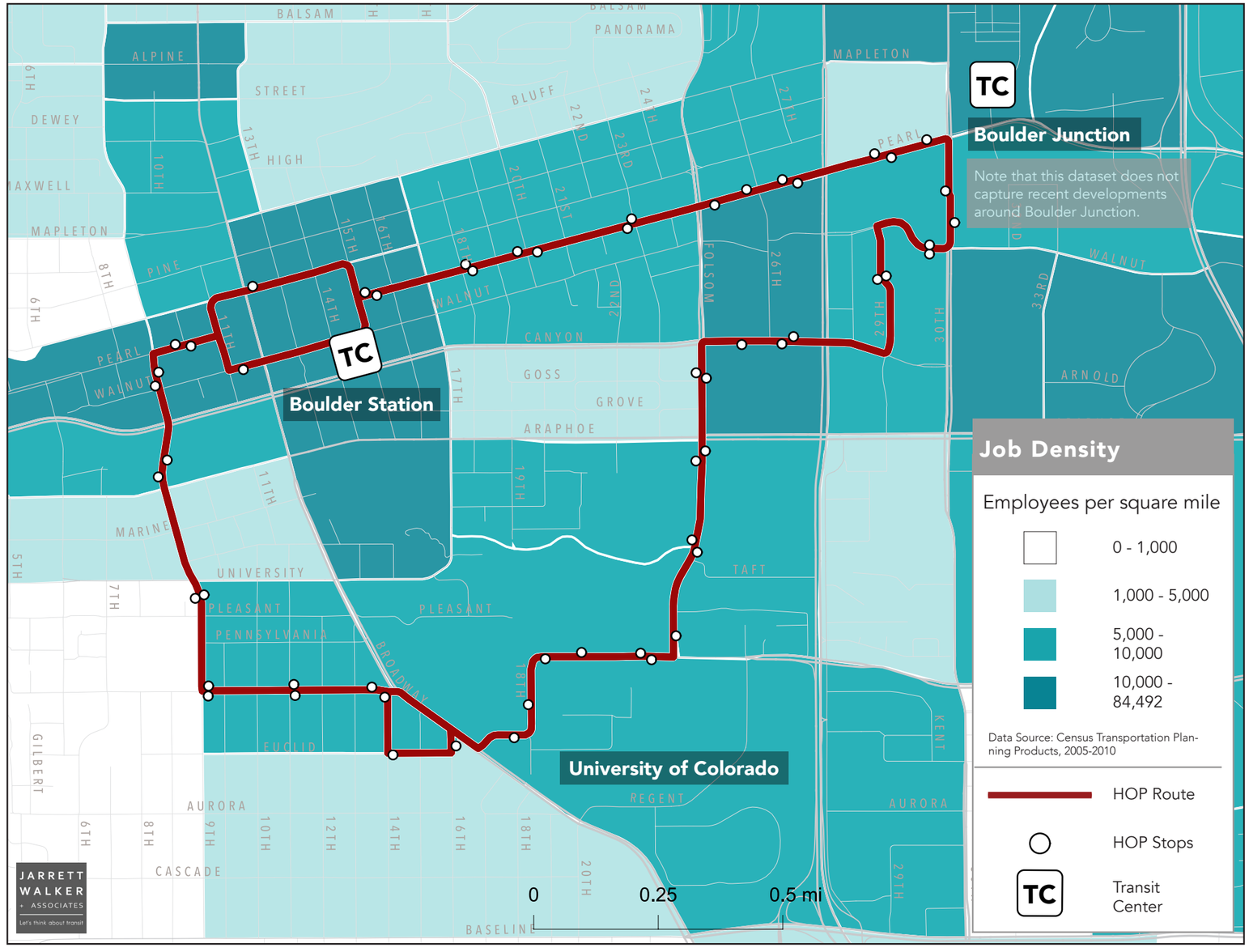



Figure 39: This map shows the density of jobs (and thereby of commercial, social and service activities) around the HOP route. Note that commercial developments since 2010 in and around Boulder Junction are not captured in this Census dataset; the area around Boulder Junction thus has even higher job densities than are shown here.

## Median Income

Figure 40 shows the median annual household income for census block groups in the central area of Boulder. Lower-income block groups are clustered around CU campus. These parts of the city contain significant amounts of student oriented housing.

Generally, block groups with lower median household incomes are found only in the developed central areas of Boulder and Longmont, while higher median household incomes (greater than $80,000) prevail elsewhere.

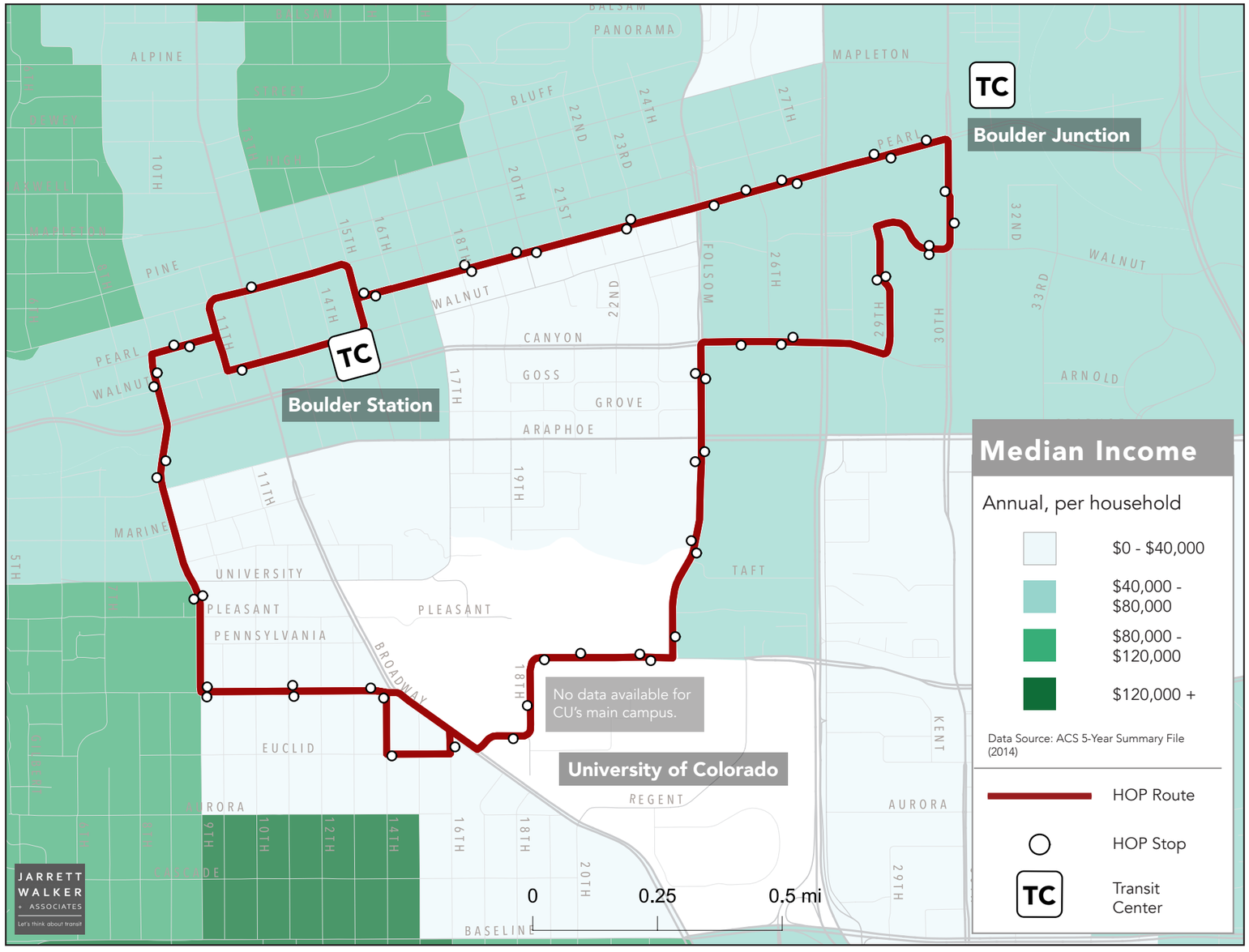



Figure 40: On this map, each Census block group is color-coded by the median household income within it. Note that some of these areas have many more households than others.

## Density of Zero-Vehicle Households

Figure 41 shows the density of zero-vehicle households in the area around the HOP. Many of the census block groups near the university with lower median household incomes are also places with a high density of households with no vehicles. This is particularly true in the area bounded by Canyon, Boulder Creek, Folsom, and 17th. In this area, over 30% of total households have no vehicle.

Where there are high numbers of people who have limited access to a car, and these people are concentrated at a high density, transit can be a very attractive mode as long as it is useful (frequent, reliable, direct, connects to other routes, etc). However, if transit isn't useful or if it is unreliable or infrequent, even people without direct access to a vehicle will likely seek other options.

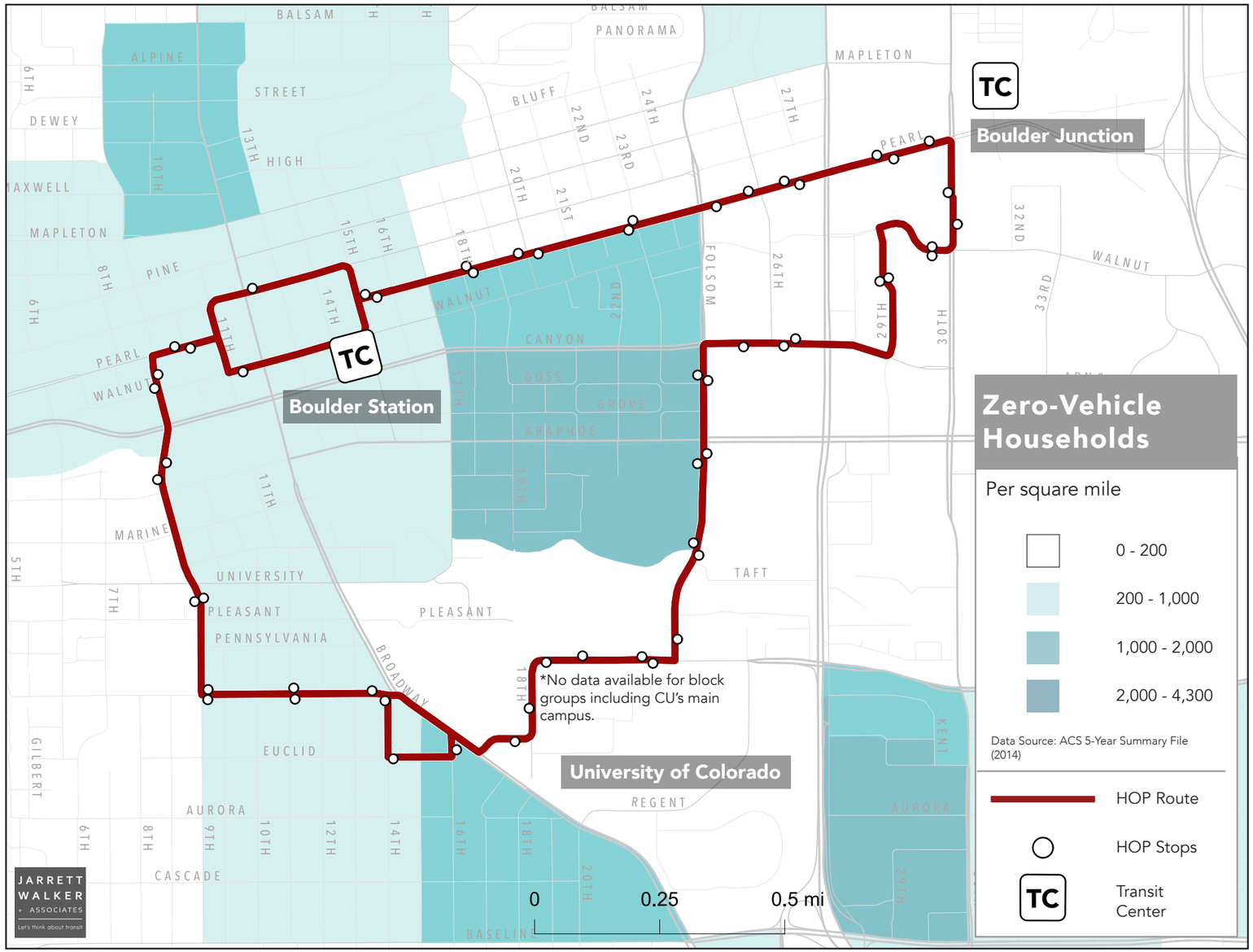



Figure 41: This map shows the density of zero-car households in each Census block group in the area around the HOP.

## Density of Young and Old Residents

Seniors (65+ years) and people too young to drive (15 and younger) have a strong incentive to use transit, and therefore can be a source of ridership. They also sometimes have a severe need for transit, which is a reason to provide low-ridership coverage services.

In part because of the concentration of the student population around the university, block groups in the center of Boulder generally have a low density of young and older people. Residential areas north, south, and east of the core area have a greater concentration of young and old people.

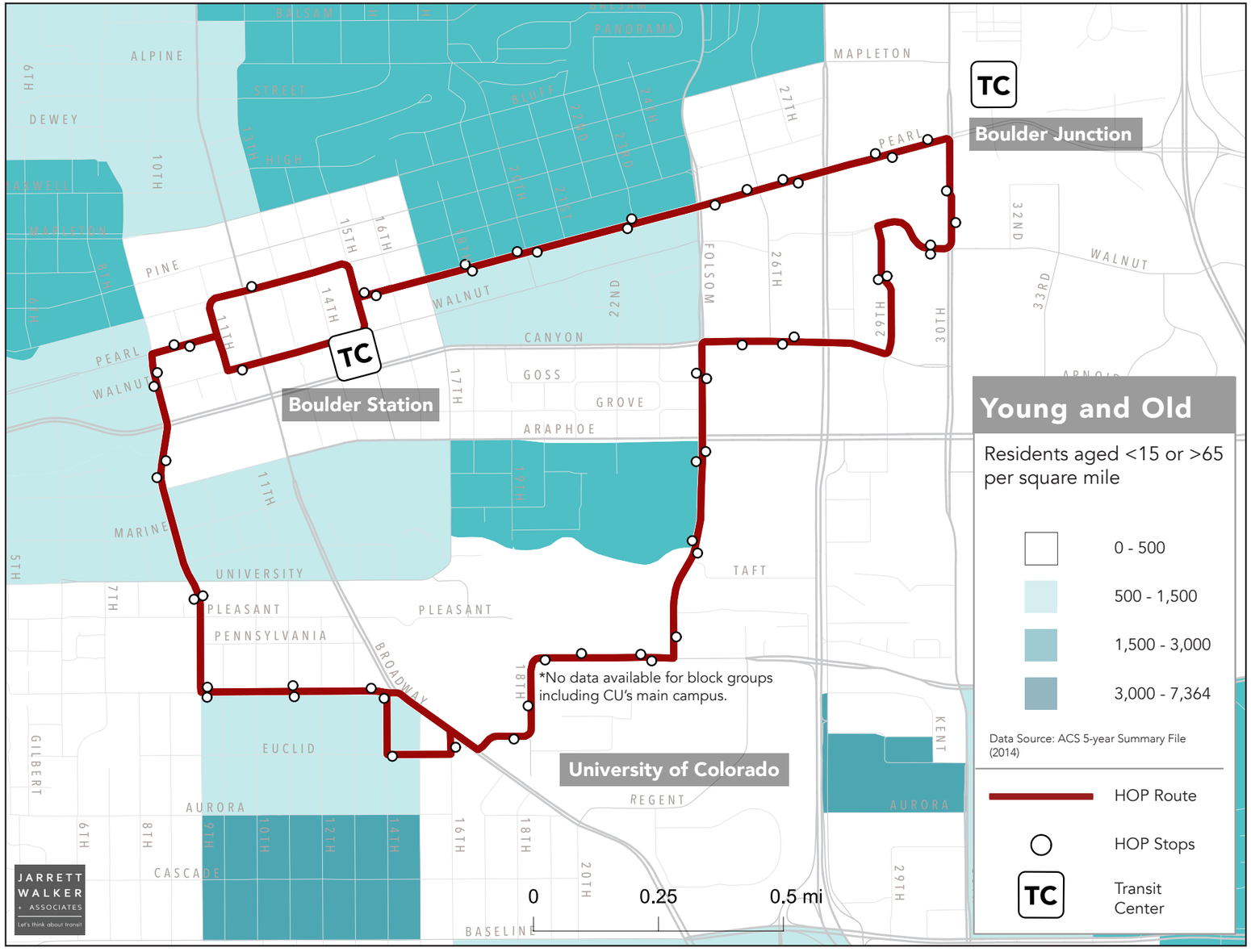



Figure 42: On this map, Census block groups are color-coded based on the density of young and old residents within them.

# B Appendix: Survey Methods

This chapter contains a description of how data was collected and analyzed in preparation of this report.

## Data collection

Ridership and transfer data was collected by JWA during a ridecheck Survey in mid-April. A ridecheck is a survey of all passengers getting on and off the bus by stop and time of day.

The Transfer Survey, done the same week as the Ridecheck, provided information on how people were using the HOP as part of a larger system.

This information was used to populate many of the charts seen in this report.

### Boardings and alightings data by stop

From Saturday April 16 through Tuesday April 19, 2016, JWA conducted a full "ridecheck," which is a count of people boarding at alighting at each stop, on every trip made by HOP vehicles.

The purpose of the Ridecheck was to collect up-to-date data on ridership on the HOP while CU was in session. The ridecheck counted passenger boardings and alightings on every trip of the HOP on one Saturday, one Sunday, one Monday, and one Tuesday, in order to develop average weekday and average weekend day estimates.

While HOP vehicles are equipped with automatic passenger counters (APCs), several problems with the calibration of the APCs and collection of the data they are capable of gathering rendered them unusable. Please note that a ridecheck is not a replacement for a functioning and validated APC system. VIA and the City of Boulder should work with their APC contractor to restore a reliable ridership reporting and data storage process for future monitoring of the route's performance.

Given the expense and difficulty of performing a manual ridecheck, many transit studies aim to collect data on every trip for as many days as possible. In some cases, this may be a single weekday; in others, a full week. Whichever is chosen, it is important to select a study period that is free from major service disruption, and reflects a normal demand condition given the overall demand pattern of the route (in the case of the HOP, a period where CU classes are in session and students are attending the campus).

The days of the ridecheck fit these criteria; there were no major service disruptions, though there was light snowfall on the Monday.

Checkers recorded boardings and alightings at every bus stop (there are 60 stops total on the route, in both directions), and they collected the arrival times of the vehicle at several mid-route timepoints. This data was used to map and analyze boardings per bus stop and passenger load per segment.

### On-time performance

In addition to counting boardings at alightings at every stop, surveyors record the time at which every HOP vehicle passed one of three timepoints. This produced the data underlying the charts on page 29, visualizing the headways between HOP vehicles throughout the day.

### Transfer Survey

The purpose of the transfer survey was to collect information on what other means of transportation people use to complete trips involving the HOP.

The survey was designed with the goal of achieving a representative sample of average weekday daily ridership, at a 5% margin of error and 95% level of confidence. Given previous estimates of average daily ridership in the range of 3,000-3,100 boardings, JWA set the target number of completed surveys at 340.

JWA conducted the transfer survey of HOP riders on Wednesday, April 20, 2016, from 7:00 am to 11:00 am, to capture both the AM rush hour and early midday travel.

Surveyors were sent out in all eight buses, each with 50 paper surveys. They stayed on their bus until those surveys were all filled out. It took between two and four hours, depending on the direction, for the surveyors to each get all of their surveys returned.

Because ridership is much heavier in the morning in the clockwise direction (due to students heading to CU), surveyors on the clockwise buses finished much faster. Every person boarding was offered a survey, very few turned it down, and 380 completed surveys were returned, about half from each direction.

**Boulder HOP Transfer Survey -** Please take a minute to fill out this survey and leave it and the pencil in one of the envelopes located at either door. Boulder will use this information to make improvements to the HOP.

1. At which stop did you get on the HOP? (Please answer 1 of the 3)
   - ◊ Street Address: _____
   - ◊ Nearest intersection: _____
   - ◊ Major point of interest: _____
2. How did you get to the stop where you got on the HOP?
   - ◊ Walked #_____ Blocks
   - ◊ Biked with my own bike
   - ◊ Biked using BikeShare
   - ◊ Drove myself
   - ◊ Was driven by someone else
   - ◊ Transferred from another bus route.
     i. If so, which route? _____
3. At which stop will you get off the HOP? (Please answer 1 of the 3)
   - ◊ Street Address: _____
   - ◊ Nearest intersection: _____
   - ◊ Major point of interest: _____
4. How will you get to that destination after you get off the HOP?
   - ◊ Will walk #_____ Blocks
   - ◊ Will bike with my own bike
   - ◊ Will bike using Boulder BikeShare
   - ◊ Will drive myself
   - ◊ Will be picked up and driven by someone else
   - ◊ Will transfer to another bus route.
     i. If so, which route? _____

Figure 43: This transfer survey was offered to all boarding passengers on a Wednesday morning in April 2016.

## Data cleaning and analysis

### Ridership by stop and load

Data from the Ridecheck were entered into a table indexed by day, direction, bus, trip, stop, and stop sequence. However, in order to calculate load (the number of people on the bus on segments between stops), it was necessary to clean the data.

Because checkers were not asked to count the number of people onboard (in addition to boardings and alightings), load is calculated by adding boardings and subtracting alightings from the load on the previous segment, starting from the first stop of the first trip of each bus each day. However, small human errors in counting can produce incorrect load calculations, such that the number of people counted boarding or alighting causes a negative load (something that is obviously not possible).

The first order correction for this error involved cross-checking all entered data with the original paper record in order to determine whether the hand-written counts had been correctly entered. Following this, small adjustments were made to counts of ons and offs where negative loads appeared (if there was an apparent error, like marking a wheelchair boarding but not a general boarding). Of course, without direct knowledge of the actual situation when the data were collected, JWA's ability to make these sorts of corrections was limited, and should be described in heuristic terms only. Corrections were made in a very small number of cases (26 of more than 10,000 records, fewer than 0.3% of the total).

Calculations of average load were made only after the exclusion of entire HOP trips on which calculated loads at any stop dipped below. In the case of data from one vehicle on one day (and one ineffective employee), enough negative loads were observed that JWA excluded all data from the vehicle for the purpose of calculating average load across the route.

One problematic employee collected inaccurate data on the Saturday of the Ridecheck, but this was not discovered until the data cleaning process. While this surveyor's data for Sunday looked mostly like others' data, it was discarded in an excess of caution. Some HOP trips from the weekends were therefore completely excluded from the dataset of boardings and alightings by stop, as well as from calculation of the loadlines. This also means that analysis and displays of Saturday ridership information are based on a smaller total dataset than for the other days.

### Transfers

Based on boardings data collected in the Ridecheck, the average daily ridership during the transfer survey was 3,350. Thus, the simple maximum margin of error at a 95% confidence level can be calculated thus:

$$0.98 \bullet \sqrt{(1/380)} = 5.03\%$$

Because of the small size of the population and large size of the sample, we can also apply a finite population correction to the margin of error to reflect this:

$$\sqrt{((3350-380)/(3350-1))} = 0.942$$

$$5.03\% \bullet 0.942 = 4.73\%$$

The chart shown in Figure 30 on page 27, reporting how many people reached the stop where they boarded the HOP by various modes, has a high *n*, because almost all transfer survey respondents answered that questions. Thus its margin of error is very close to that of the entire transfer dataset.

The chart shown in Figure 31 on page 27, by contrast, reflects data from a small number of respondents (*n*=49) and thus should not be taken as representative of the entire population of weekday HOP riders.

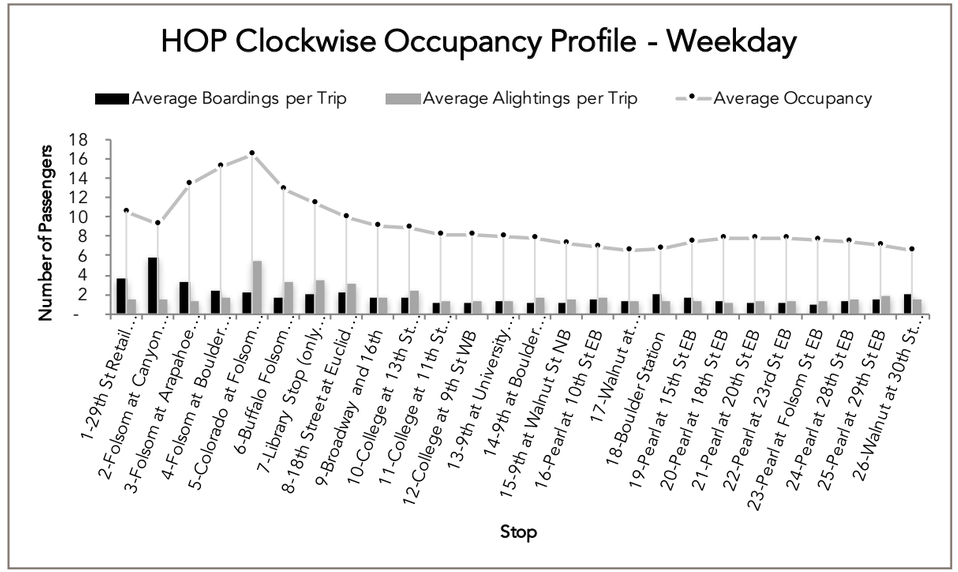
As noted in the text on that same page, additional information was also gathered about the particular routes from which those transferring passengers reached the HOP. The number of respondents answering that sub-question was also too low for their responses to be taken as representative of the entire population of HOP riders.

### Loadlines

The orange "loadlines" diagram (such as in Figure 27 on page 25) was created using weekday occupancy data. Occupancy is the average number of passengers on board the bus at each point on the route. It is calculated by summing boardings and alightings for all trips of each vehicle, starting from the first trip of the day. As noted at left, a few HOP trips were excluded from this analysis due to obviously-erroneous negative loads.

Figure 44 shows ridership and occupancy - at each stop, the bars of the graph represent the number of ons and offs, while the line represents the average occupancy.

The charts on the following page show load profiles for the surveyed Saturday and Sunday.



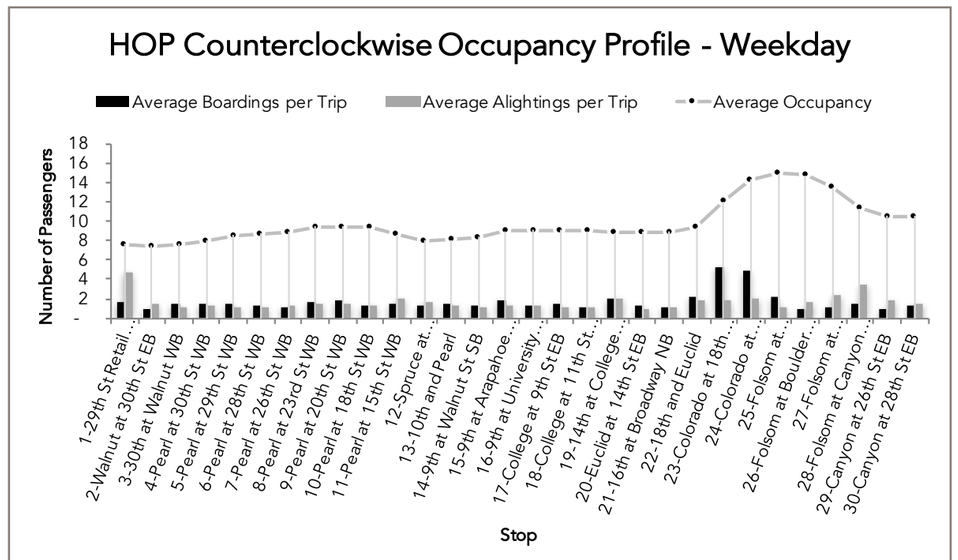
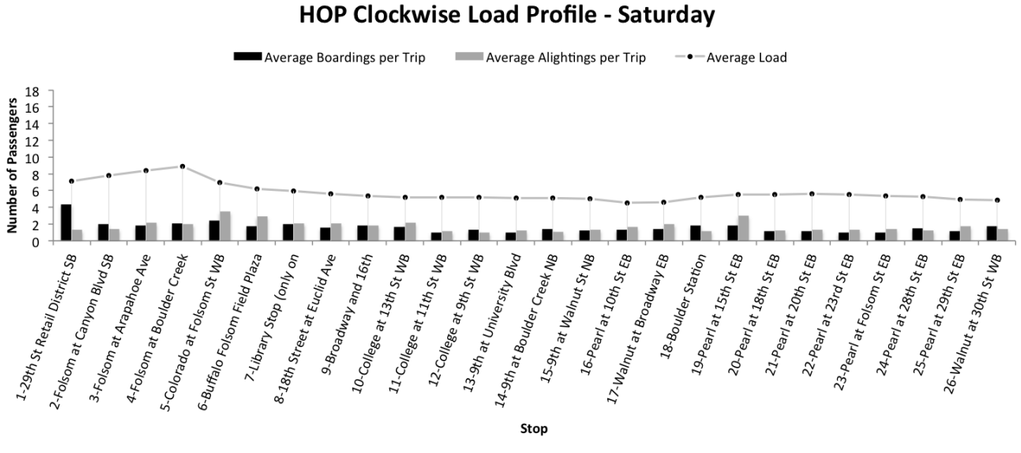




Figure 44: These charts display both boardings and alightings data for each stop (black and grey columns) and the average daily passenger load inside HOP vehicles between each pair of stops (the dashed line).



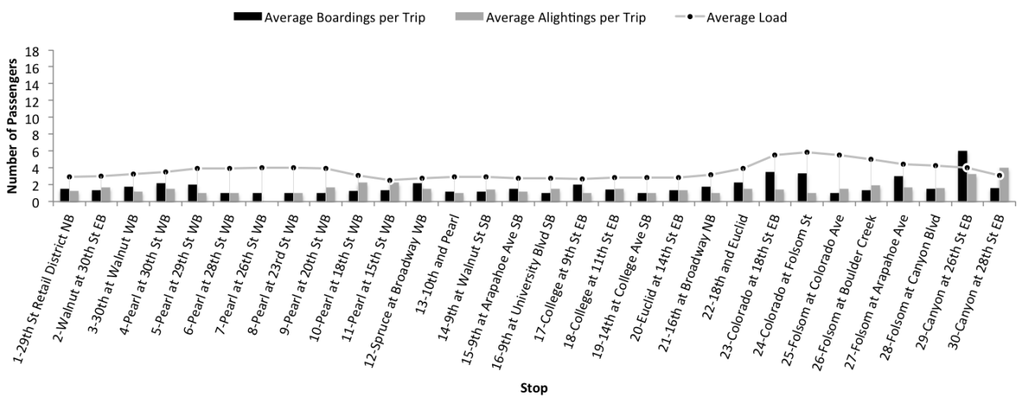
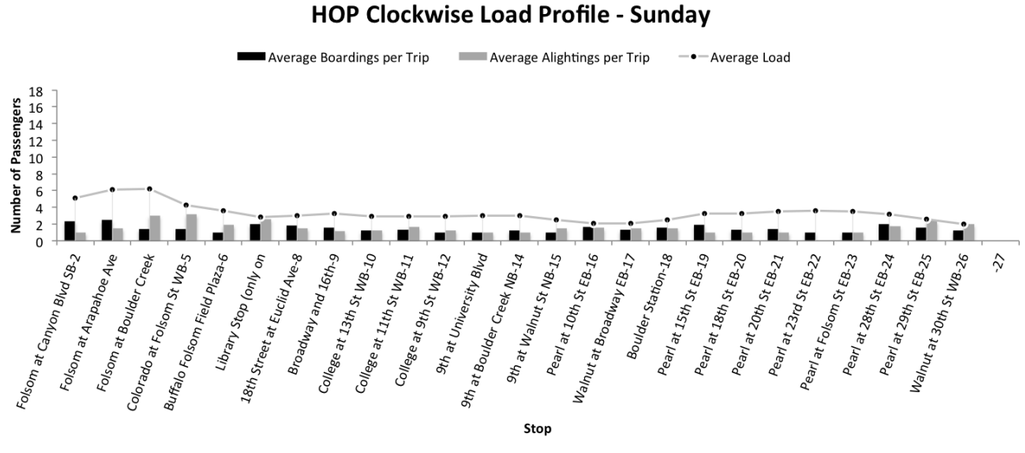




Figure 45: Average occupancy on the HOP between all stops, on Saturday. This is based on a count of boardings and alightings of 75% of HOP vehicle trips, because some suspicious data was discarded.



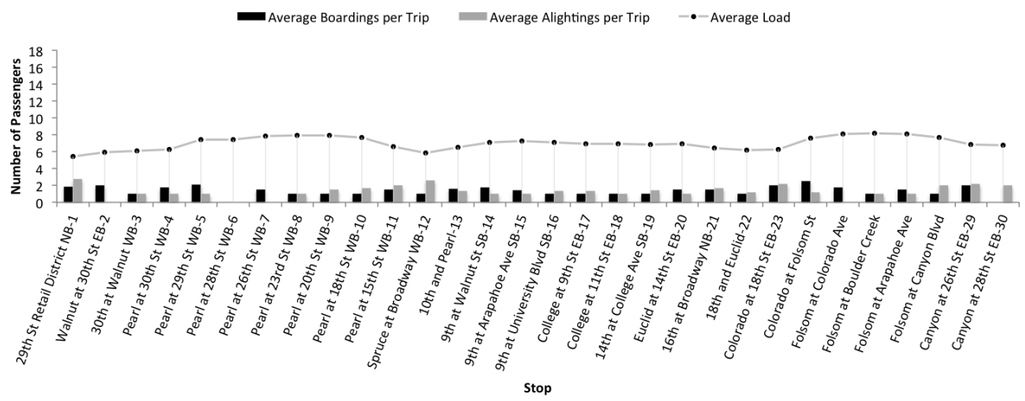




Figure 46: Average occupancy on Sunday. This is based on a count of boardings and alightings of 75% of HOP vehicle trips, because some suspicious data was discarded.